A PRIMER OF EVOLUTION

EDWARD CLODD

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A PRIMER OF

EVOLUTION

BY

EDWARD CLODD

PRESIDENT OF THE FOLK LORE SOCIETY

AUTHOR OF
"THE STORY OF CREATION," "THE CHILDHOOD OF THE WORLD,"
ETC., ETC.

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TO THE

RIGHT HON. THOMAS HENRY HUXLEY

P.C. D.C.L. LL.D. F.R.S. &c.

My dear Mr Huxley,

The permission which you kindly give me to dedicate this little book to you enables me to publicly acknowledge my indebtedness for the stimulus and help afforded by your writings—the choice companions of many years.

Let me testify that while their charm lies in your luminous treatment of the varied materials with which it is the province of science to deal, their permanence is assured in your application of those materials to the construction of an all-embracing philosophy of life.

Believe me

Yours sincerely and gratefully

EDWARD CLODD

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PREFATORY NOTE.

The reception accorded to the 'Story of Creation' has induced me to prepare this abridgment of that book, omitting, it is hoped, nothing essential to a general understanding of the theory of Evolution. I wish to thank my publishers for enabling me to issue the work at a price that brings it within the reach of all.

E. C.

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PART I.—DESCRIPTIVE.

CHAPTER I.

THE CONTENTS OF THE UNIVERSE.

The Universe is made up of Matter and Motion. Or, to put this in other words, the Universe is made up of distinct particles which are never still, whether they compose things dead or living. The myriad particles of which the sparkling diamond or a piece of rusty iron consist are swinging backwards and forwards among themselves in rhythmic measure, millions of times every second. As for living things, the old Norse myth that tells how Heimdal, having drunk of the well of wisdom, could hear the grass grow, holds, like many another ancient tale, some truth which the myth-maker saw dimly, and which science has made clear. For, were our ears sharp enough to catch the murmur of the currents whirling in the millions of cells which build up the green blades that cover the meadows, 'we should be stunned as with the roar of a great city.'

Matter is the stuff or substance which occupies space. It is familiar to us in three states: *solid*,

liquid, and *gaseous* (which term includes the *vapourous*), and it pervades all space in a highly diffused state called *ether*, which is perhaps the raw material, as we may say, of the other states.

In the *solid* state, Matter is more or less rigid, resisting any attempt to alter its shape or size, unless violent force is used. Some solids are less rigid or more yielding than others, as, for example, a piece of indiarubber compared with a piece of iron; but, speaking broadly, we define a solid body to be that which keeps the same volume or shape.

In the *liquid* state, Matter always takes the shape of the vessel into which it is poured, spreading out so as to make its surface level. It cannot be compressed; a quart of water will not go into a pint pot.

In the *gaseous* state, Matter has no surface, it is shapeless and wholly fills the vessel which contains it, but it can be pressed into a much smaller space.

In the *ethereal* state, Matter is enormously elastic; it fills not only the vast spaces between earth and sun, and between sun and stars, but also the minute spaces between the particles that make up the smallest masses of Matter.

There is no hard and fast line between any of these states, Matter being solid or sticky, liquid or vapourous, according to temperature; or, in other words, according to the motions which bind the particles together, or drive them further apart. It is possible by extreme cold and pressure to make even air and some other gases solid, while all known simple substances can be brought into the gaseous state by the separating ac-

tion of heat. The *ultimate nature* of Matter is unknown, but we know something of its structure and properties by learning *what it does*. It is made up of chemical units or elements, of which about seventy have, to the present time, been discovered. These elements are named *atoms* (from a Greek word meaning 'that which cannot be cut') because, as yet, they have never been divided. When united together they are called *molecules*, although even then they are at a certain distance from each other. And those which unite always do so in the same proportions both as to weight and volume. For example, whether we take water from a tumbler or from the ocean, each of the molecules of which it is composed contains sixteen parts by weight of oxygen to two parts by weight of hydrogen. Again, certain atoms unite more readily with certain other atoms. But amidst all changes, they remain unchanged. It signifies not into how many myriad combinations; into how many myriad substances,—animal, plant, or mineral,—the atoms have entered; neither how many millions of years have elapsed to bring about these changes; the atoms are neither worn nor weakened. In other words, *Matter cannot be destroyed*. But although Matter takes such infinite variety of form, nearly everything familiar to us,—and the same may apply to things unfamiliar —is made up of only two, or, in a few cases, four elements. For example, oxygen, the most important and abundant of all, and, by itself, both tasteless and invisible, composes nearly one-half of the rocks of the earth's crust, while every living thing, from a mere

jelly-speck to man, is *mainly* built up of four elements —carbon, oxygen, hydrogen, and nitrogen.

The saying of a wise man, that 'bigness isn't greatness,' holds good throughout the universe, for the tiniest mass of matter may be as complex as the molecules which make up the largest bodies of the heavens. Many experiments and calculations have been made to find out the size of atoms, but our minds cannot grasp the meaning which the rows of figures seek to convey. For example, the seven hundred-millionth part of an inch is a great deal over the thickness to which, if it could be done, a plate of zinc or copper could be reduced without making it cease to be zinc or copper as we know and handle them. The size of a molecule of water is about one fifty-millionth of an inch in diameter; that is to say, if a drop of water the size of a pea was enlarged to the size of the earth, the molecules would be about as big as cricket balls. But, as helping to illustrate how unable we are to grasp the idea of the minuteness of an atom, the most powerful microscope brings us no nearer any knowledge of the ultimate structure of the atom than we should be to knowledge of what is printed in a newspaper seen with the naked eye about six hundred yards off.

Matter will not move by itself: it needs some agent or cause to start it. Therefore all changes in the position of bodies, as also all changes in the position of the molecules of which they are made up, and of the atoms which form the molecules, are due to MOTION, which works in two opposite ways.

In the one, it draws the particles of bodies together; in the other it separates them.

A. In *drawing them together*, when acting between *visible masses*, large or small, near or distant, as between a man and the ground he stands on, or between the earth and the sun, it is called *gravitation*. This is the force which causes every body to fall when it is set free. When it acts between *molecules* composing masses of matter, it is called *molecular attraction* or *cohesion*. When it acts between *atoms*, uniting them chemically into molecules, it is called *chemical attraction* or *affinity*.

B. The Motion or Energy which *separates the particles*, or which *prevents them from coming closer together* is of two kinds, *active* or *kinetic*, and *passive* or *potential*. The *passive* kind is represented by a stone lying on a roof or a mountain side, by a clock wound up but not set going, by a seam of coal, and so on. The *active* kind is represented by the stone falling, the clock going, and the coal burning. Like Proteus, the old man of the sea in Greek myth, who could assume every possible shape, yet remain the same, Energy undergoes all kinds of transformations, yet is itself unchanged. Not only does a definite amount of any one form of Energy pass into an equivalent amount of the other form—motion into heat, light into electricity, or *vice versa*—but the tendency of all passive Energy is to be converted into active Energy which again becomes less and less active, until a dead or uniform level is reached. For example, directly water is converted into steam by the action of heat,

it begins to condense unless the heat is maintained, and falls to an even temperature. The significance of the continuous passing of Energy to a state in which it can do no work will appear later on. But whether active or passive, the sum-total of Energy in the universe is a fixed quantity; like Matter, *it is indestructible*. This is known as the doctrine of the CONSERVATION OF ENERGY.

The modes of Motion which have been described above perform the work of the universe between them. Gravitation, Molecular Attraction, and Chemical Attraction are ceaselessly acting as pulling forces. Light, heat, electricity, and other forms of Energy are pushing forces. And with the opposing action of the two the continuance of the universe is bound up. For, if the pulling motions had unresisted play, every particle of Matter would gravitate to a common centre and so form a vast solid body, inert and lifeless. And if the pushing motions had unresisted play, every particle of Matter would be separated and scattered as an enormous gaseous mass through space. Whereas, with the *push* and *pull* motions, Matter is in a state of ceaseless change, whether in the bodies which move from one place to another, or in the backwards and forwards movements of the particles which make up bodies like those of the diamond; and, to take another example, of hydrogen gas, the rebounds in which number seventeen thousand millions per second. Yet the vibratory dance of these is slow compared with the oscillations of light-waves, which number hundreds of millions of millions per second. Light speeds through space at

the rate of 186,300 miles per second, and therefore, as the sun is about ninety-three million miles from the earth, the light takes eight minutes to reach us. From Alpha Centauri, the nearest "fixed" star, it takes four years and four months; from the brilliant star Aldebaran it takes twenty-seven years; while stars of the sixteenth light-magnitude may be so far away from our system that it would take a wave of light 36,000 years to reach us.

Now, it is this transmission of light, and other forms of Energy, between bodies far and near, that warrants the belief in the existence of Matter in an *ethereal* state. Sir Isaac Newton said that to conceive of one body acting upon another body through a vacuum is so great an absurdity that no thinking man could ever fall into it. Therefore, to account for the motions between the particles of Matter and between the distant bodies in space, we can do no other than assume that they are caused by the tremors or vibrations of a highly tenuous elastic medium called Ether, which fills the intervals between atom and atom in the tiniest body, between molecule and molecule everywhere, and also the vast spaces between earth and sun, and sun and stars, to the remotest stellar system. That Matter should thus exist in an ethereal state may not so much surprise us when we remember into what other invisible states it passes before our very eyes; as, for example, when water is vaporised into steam, which we never see, because the moment that what we commonly call steam appears, condensation has begun. As will be seen, the assumption of

an ether is not the only instance where Science asks us to take something for granted as a necessary step to the discovery of truth. But whenever Imagination or Faith are thus called in, this is to quicken, not to excuse, enquiry, so that all beliefs may, in the last resort, have the sanction of Reason.

CHAPTER II.

THE DISTRIBUTION OF MATTER.

We have learned that Matter is invisible as well as visible; and ponderable or weighable, as well as imponderable. In its imponderable or ethereal form, it fills the intervals between the atoms which compose all bodies, and the enormous intervals between the bodies themselves. In its ponderable form it is distributed through space in bodies of varying densities.

Dealing with the greater masses, we have—as the sand by the sea-shore innumerable—the 'fixed' stars, so called because, owing to their vast distances from us, they have no apparent motion of their own, although travelling at enormous speed. Each of these, unless it be an extinct, burnt-out body, shines by its own light as our sun does, and, like him, is probably the centre of a system of planets with their satellites or moons, and other bodies. Speaking broadly, the stars do not differ from one another in the stuff of which they are made, for the light thrown by the spectroscope on the chemistry of the heavenly bodies has revealed their general identity of structure. It matters not how distant is the star, so long as the light which it radiates is strong enough; broken on the prism of the

spectroscope, it tells what elements are present in the glowing vapour, and even the direction in which the star is moving. Stars differ very much in their sizes and brilliancy or 'magnitude,' while their various colours probably give a clue to their stage of development. White stars, many of which are closely connected with nebulous matter, are probably in the earlier stages of formation into solar systems; those whose spectra correspond to the solar spectrum will have reached the sunlike state; while the red stars would be approaching the decrepit stage which precedes the blotting-out of their light, when their presence, like that of Algol's dark companion, is known only by their influence upon the movements of other stars through the force of gravitation.

No certain conclusions have yet been reached as to the general distribution of matter in space; in other words, as to the form of the stellar system. As seen from the earth, the combinations are varied and complex. The nearness of certain stars to other stars is often apparent, being then due to their lying in nearly the same straight line from our system. Besides double and multiple stars, there are the larger groups called constellations, whose names are often relics of beliefs of uncivilized peoples that the stars were once men or animals, as Orion, and the Great Bear. Then there are star-clusters where suns seem so huddled together as to look like mere cloud-patches, outlines of the irregular band known as the Milky Way. About ninety per cent. of the stars lie in this region. The naked eye can see between two and three thou-

sand stars at the same place and time, but the photographic chart of the heavens which is now in progress, and which will include all stars down to the fourteenth magnitude, will, it is computed, show about twenty millions, or one-fifth of the total number visible in our largest telescopes.

Besides the fixed stars and their systems, straggling in scattered groups on either side of the Milky Way, or composing its cloud-like arch, and besides the stellar nebulæ (from Latin *nebula*, a cloud), which the telescope shows are composed of stars, there are the vast masses of glowing matter called gaseous nebulæ. These are of various shapes,—circular, elliptical, spiral—and are the raw material of which suns and systems are formed.

These nebulæ: the fixed stars, with whatever belongs to the system of each; the wandering comets; and the myriad meteor streams, the smaller members of which strike our atmosphere as 'falling stars,' and either reach the earth as aërolites, or are dissipated into fine dust, some of which sinks into the deep ocean—comprise the ponderable matter of the universe. The imponderable is that ethereal medium which, as has been shown, is the vehicle of Energy.

CHAPTER III.

THE SOLAR SYSTEM.

THE star nearest to us is known as the *Sun*, and the system connected with him comprises the *Earth* and other *Planets*, their *Moons*, certain *Comets*, and *Meteors* or *Shooting Stars*.

The *Sun* is a mass of gas burning at so high a temperature that all the chemical elements of which it is composed are in a state of vapour. So enormous, however, is the pressure that, although the heat renders their combination impossible, they have the density of liquids. But in the 'photosphere,' as the visible surface of the sun is called, cooling by radiation renders combinations of the elements possible. As seen through a telescope the photosphere appears to be covered with mottled clouds, which are frequently torn and agitated by irregularly-shaped spots,—vast shifting cavities, the centres of terrific activities. It is surrounded by a gaseous, scarlet-coloured shell called the 'chromosphere,' from which glowing ruddy masses of hydrogen gas are projected thousands of miles at varying rates, sometimes 600 miles per second; while surrounding the 'chromosphere' is the pearl-coloured 'corona,' seen only during total solar eclipses.

Vast as is the sun's volume, exceeding several hundred times that of all the members of his system put together, he is by no means the biggest or brightest of the stars. But none of these are of any importance to us as compared with him, since it is to his enormous and ceaseless emission of heat and other forms of energy that life and all its powers are sustained on the earth. And yet, of the energy radiated from every part of his surface in all directions, the planets, large, small, and minor, receive or intercept only the two hundred and thirty millionth part, the earth receiving but the two thousand one hundred and seventy millionth part! Even of this tiny proportion, a large amount falls upon the earth only to be immediately radiated into space, whither the whole of it finally goes.

The *planets*, one and all, revolve in nearly circular orbits round the sun in virtue of the energy of orbital motion which each possessed at the beginning, and which counteracts the opposing force of the sun's gravitation whereby they would otherwise be pulled into him and swallowed in his mass. If we include, as worthy of rank with them, the swarm of minor planets or asteroids of which new ones are being frequently discovered, they are perhaps to be numbered by thousands. Like the stars, they are in different stages of progress and decay. Some, as the earth and Venus, at least in her polar regions, have cooled down sufficiently to be covered by a hard crust, and to be fit abodes for living creatures; others, like Jupiter and his fellow giant planets, are still in a more or less heated and partly

self-luminous condition. The smaller bodies, as, for example, our moon, have long been cold and inert, and are now what the planets and the great sun himself will one day become. As will be shown later on, the tendency of all bodies is to pass from the gaseous, through gradual stages of cooling, to the solid state.

The *moons* revolve round their several planets under similar conditions as the planets round the sun. The gaseous masses, composing *comets* and the countless *meteor streams*, travel in very eccentric orbits. Only a few of the comets which have visited our system have ever returned.

The *earth* is of nearly spherical shape, being slightly flattened at the poles and bulged towards the equator. It consists of a core within a hard crust; seven-tenths of its surface is covered by water, and the whole of it is surrounded by an atmosphere or gaseous envelope probably extending two hundred miles above the surface, but decreasing in density till its limits melt into space. The entire mass spins on its axis at the rate of about 1,000 miles every hour, and speeds through space in its orbit round the sun at the rate of 19 miles every second.

The atmosphere is composed, in the main, of the uncombined elements oxygen and nitrogen; the water is chiefly compounded of combined but mobile oxygen and hydrogen. Of every hundred parts of the crust, ninety-nine are made up of about sixteen out of the seventy elementary substances, and of these sixteen the larger number exist in small proportion. Nearly one-half of the crust consists of oxygen which

it has taken into itself from the atmosphere, and it is computed that already one-third of the water of the ocean has been absorbed by minerals. The average density of the earth is about five times and a half that of a body of the same size made of pure water, but the large extent covered by the ocean in the southern hemisphere, whither the tendency to collect was probably manifest at the outset when the steamy vapours condensed and filled the depressions in the crust, points to an excess of density in that direction.

The crust was never uniformly smooth, for the shrinkage of the mass as it cooled would cause shrinkage of the surface, producing intense heat. Hence the beginnings of the wrinkled, cracked, and crumpled features which the action of air and water would help to score more deeply on the earth's rugged face. The cavities filled by the great oceans—in some places above five miles deep—were probably thus formed, and have remained what they were at the beginning; all changes of land and water having taken place in relatively shallow seas. Our knowledge of the crust reaches but a little way down, for the total thickness of the layers of rock already measured is barely thirty-six miles, or the one hundred and tenth part of the earth's semidiameter. What the inside of the earth is like no man can tell. It may be solid throughout, or it may be fluid or viscous a few miles beneath the crust or skin. Whatever its state, we know from the action of volcanoes and earthquakes that it has not yet lost the whole of the original store of energy in the

form of heat which it acquired as the molecules of which it is built up drew closer together under the action of gravitation.

Although we always connect the term 'rock' with hardness, it is applied by geologists to all materials of the earth's crust, whether drifting sand or swampy mud or granite.

Rocks are divided into two classes — *unstratified* and *stratified*. The *unstratified*, which are also called igneous or Plutonic (from the Greek Pluto, ruler of the dark underworld), include all rocks which, as they now exist, have been fused together by heat, or erupted from the earth's interior by volcanic agency. The *stratified*, which are also called aqueous or Neptunic (from the Roman sea-god Neptune), include all rocks which have been deposited as sediment by the action of water or of the atmosphere, or which are due to the growth and decay of plants and animals. With this class are grouped the *metamorphic*, for the most part stratified rocks which have been changed into a crystalline state by the action of heat and pressure, resulting in effacement of their original character, and in the destruction of traces of any organic remains in them. Throughout the entire series of rocks the newer have been, and are being, formed out of the older, which, unless upheaved, are always found at the bottom; but of the original crust probably no trace remains.

The depth to which the *unstratified* rocks extend is unknown, and as they contain no organic remains they tell us nothing concerning the origin and suc-

cession of life on the earth. The *stratified* rocks, which alone throw light on this question, have been divided for convenience, and not as implying any gaps between their several formations save where natural causes have operated, into five epochs. These, together with the typical remains of plant and animal associated with each, are as follows : —

Epoch.	Estimated Thickness of Strata.	Typical Plant.	Typical Animal.
Archæan or Eozoic (*dawn life*), chiefly metamorphic.	30,000 feet.	Algæ.	Monera.
Primary or Palæozoic (*ancient life*).	106,000 "	Ferns.	Fishes.
Secondary or Mesozoic (*middle life*).	25,000 "	Pine forests.	Reptiles.
Tertiary or Cainozoic (*recent life*).	27,000 "	Leaf-bearing forests.	Mammals.
Quaternary or Post-Tertiary.	600 "	Existing	species.

CHAPTER IV.

THE EARTH: ITS PAST LIFE-HISTORY.

GEOLOGY deals with the stuff of which the earth is made; its origin, structure, and arrangement. But so interrelated is the material of which all things are formed, that inquiry into the structure of rocks has to be extended wellnigh at the outset to their contents—that is, to the fossil remains of ancient life which are not only preserved within the larger number of strata, but entirely compose vast masses, as coal-beds, chalk hills, and coral islands. Therefore the interest which the study of the erupted, fire-fused, and water-laid rocks awakens, especially in their witness to ceaseless changes through an ever-receding past, becomes more immediate and human when the relics of ancient life-forms are examined; and when their appearance, persistence, or disappearance, their order and succession in an ever-varying, ever-ascending scale, are traced. For in them lies the record of life on the earth through measureless time; the life that was, parent of all life that is; from simple slime-speck to man.

The record is very imperfect, the gaps are wide and frequent. But when we think of the continuous play of fire and water upon the formations, and how the same rocks have been used over and over again, to

the mutilation or destruction of their fossil contents, the wonder is that so much is left whereby the ancient forms of life can be rebuilt one by one.

So far as the vast number of the lowest plants and animals are concerned, it is impossible that any actual remains of these should have been preserved. For they were soft-bodied, and it is only the harder materials of plants and animals, the bark, wood, and seeds of the one ; the shells or skeletons of the other, that would survive, and even the preservation of these in fossil form is dependent upon the nature and permanence of the beds in which they were interred. As it is, but a remnant of all that ever lived in the water—the birth-place of life—and a far less proportion of the smaller population of the land, are represented by actual fragments. Sometimes the only trace that such and such a creature lived is in the cast or mould of a shell or of a footprint on the mud of a far-off time. Sometimes, when the fossil itself has perished, its form has been perfectly replaced by the chemical process of 'petrifaction.'

The igneous rocks are rich in mineral veins and ores, but, except where recent plants and animals have been accidentally enveloped in the soft lava ejected by volcanoes, they are destitute of fossils.

There was a period in the earth's history when life was not, and its beginnings, which, as will be shown hereafter, were probably in polar regions, were certainly subsequent to the ejection of the molten or pasty masses which cooled into true volcanic or fire-formed rocks.

Although fossils are found only in sedimentary or water-laid rocks, they are not everywhere present in them. These rocks are varied and mixed in their composition, but they can be grouped under two heads: 1. Those derived from sediment in its several states of gravel, sand, and mud; and 2. Those formed of the remains of plants and animals, as, for example, coal-beds and chalk deposits. But no matter what their source, or however much they have been tilted or heaped one above the other by upheavals from beneath, there is a fixed succession between them. Each layer has its own type of plant or animal which enables its place in the order of water-laid rocks to be known. There are no hard and fast lines in these types; some of the lower and simpler life-forms persist through all the strata, simplicity of structure ensuring permanence; and there is a general merging of one type into another, as, for example, of birds with certain features of reptiles, and so forth. Some of the links may be missing, and perhaps will never be found, but the chain was once complete.

The stratified rocks are subdivided into the systems shown on page 21. There is no one section of the earth's crust where a complete series is to be found with layer superposed on layer like the skins of an onion; but whatever gaps exist locally do not affect the relative age and place of each stratum, which, as remarked above, are fixed by the fossils.

1. ARCHÆAN and PRIMARY.— The *Laurentian* rocks, vast and venerable sediments of primeval seas, are highly metamorphic. Heat, moisture, and enor-

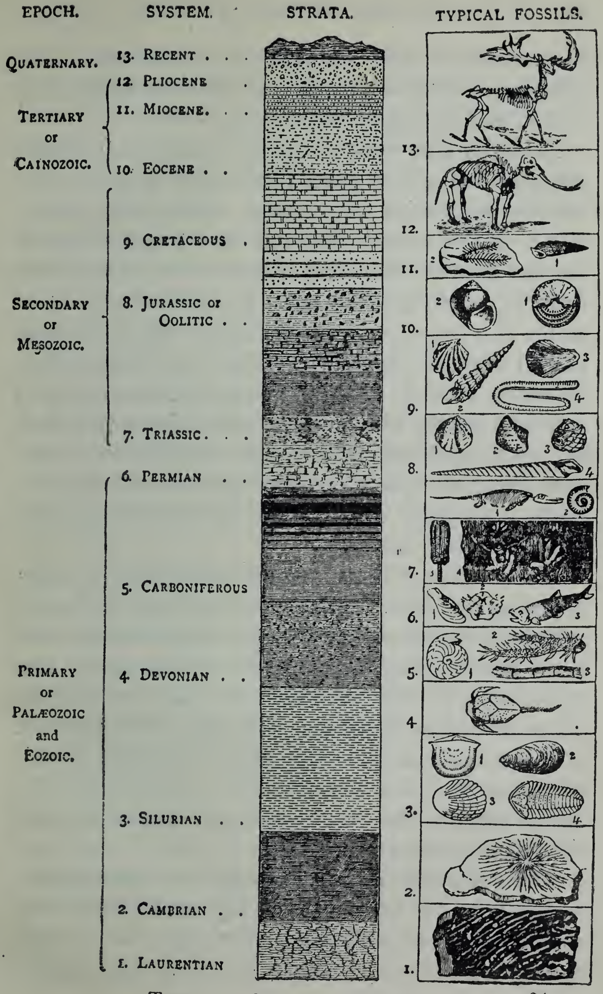


TABLE OF STRATIFIED ROCKS.

mous pressure have changed their sandstones into sparkling crystalline rocks, and their limestones into veined and variegated serpentines.

Formerly they were classed as 'Azoic'—*i.e.*, without life; but of late years those which form the Laurentian Mountains in Canada, whence the general name of the series is derived, have acquired special interest from the discovery of certain veined structures in them, pronounced by some authorities to be the remains of a large foraminiferal animal which has been named *Eozoon Canadense*. The foraminifera (Lat. *forāmen*, a hole), form perforated shell-coverings of exquisite beauty from the lime which they secrete from the water, and it is shells of this character that compose the chalk and limestone deposits. All these deposits have been laid in relatively shallow seas, and not in the deep oceans.

While some of these low-life forms secrete chalk, others secrete flint. Among the latter are the lovely, minute plants known as diatoms, whose remains compose, among other deposits, the 'rotten-stone' used as polishing powder, of which no less than forty-one thousand million skeletons go to make up a cubic inch.

It matters little if, as now seems likely, the organic character of *Eozoon Canadense* be disproved, for other traces remain that the Laurentian waters swarmed with living things of low type.

The *Cambrian* rocks, although less metamorphic, add little to our knowledge of primitive plant-forms, such as are preserved being perhaps algæ, or seaweed, corresponding to the tangles covering large areas of

the Atlantic, especially the region called the Sargasso Sea. But the system is fairly rich in fossils of marine animals, themselves the descendants of a long line of perished ancestors. Sponges, sea-lilies, and low forms of mollusca or true shell-fish, are found; but the typical and most perfect fossil is that of the three-lobed crustaceans called trilobites, which swarmed in those ancient seas, and survived till the Carboniferous period. Quite recently, remains of trilobites with antennæ have been found.

The *Silurian* rocks, although exhibiting in crumpled and rugged mountain-chains the action of agents both above and below the earth, are much less metamorphosed than the preceding systems. They are in large measure the worn fragments of land areas which stretched across Northern Europe for above two hundred miles into the Atlantic, the sediment being deposited in a shallow sea which then covered Central and Southern Europe, and the floor of which was slowly raised as a primitive European continent at the close of the Silurian period by subterranean movements. The land plants, which are the earliest as yet met with, are allied to huge club-mosses, ancestors of the gigantic forest-kings of Devonian and Carboniferous times. The most ancient of all known land animals is a scorpion found in the upper Silurian beds of both Scotland and Sweden; while the marine remains are varied and numerous, comprising sea-weeds, foraminifera, corals, star-fish, shell-fish of every kind, trilobites, and huger lobster-like crustaceans sometimes measuring above six feet in length.

But the most important fossils are those of the earliest known vertebrates, in the form of armoured fishes, allied to the sturgeon, and called ganoids (Gr. *ganos*, splendour; and *eidos*, form), from the brilliancy of their enamelled scales.

In this seemingly sudden appearance of highly organised animals marking so great an advance in structure on the higher invertebrates, the imperfection of the geological record is brought home to us. For if later forms are modified descendants of earlier, then not only are the transitional ancestral forms of the ganoids missing, but the species itself is enormously older than the fossils imply. But we need not despair; only a limited portion of the dry land has as yet been explored with any completeness, and there are vast fossil-holding areas submerged and inaccessible; yet one by one missing links are being found. Probably the predecessors of the ganoids, the skeletons of which are cartilaginous, were of a structure too soft to permit of their preservation in a fossil state.

The *Devonian* and *Old Red Sandstone* rocks, while evidencing frequent redistribution of sea and land, have undergone, as compared with the older systems of the Primary epoch, but slight disturbance from the upheaving and contorting agencies beneath. They are widely diffused, extending far north within the Arctic circle; and although their fossil contents are very incomplete, they bring less fragmentary witnesses to that continuity of life the record of which is so markedly broken in more ancient deposits. This is specially

apparent in the relative abundance of vegetable remains, by which we may for the first time construct some picture of plant-life on the globe in Palæozoic times. Not only do we find huge tree-like plants of which our club-mosses and ferns are pigmy representatives, but true trees, as proven by the concentric rings of growth in their trunks. Of land animals, the preservation of which is so rare in all deposits, there are no traces; no reptiles wallow in the lagoons and marshy flats, neither are the verdant yet flowerless forests brightened by the plumage, nor their stillness broken by the song, of birds. But we find the earliest known insects; some happy chance, like that which envelops the insects of Tertiary forests in amber—the fossil resin of conifers, or pines and firs,—has preserved a fragile wing, with the remains of a stridulating organ attached, as in the grasshopper and cricket, wherewith then, as now, mates were attracted or rivals challenged—perchance 'the first music of living things that geology as yet reveals.'

Fresh-water fossils abound, but the predominant types are marine—large sponges and corals; 'lamp-shell' mollusca, which have persisted in varying forms from Cambrian times to the present; crustaceans huger than any that have lived since, and of which even the spawn masses are sometimes preserved. More or less special types appear and then vanish, through inability to adapt themselves to new surroundings and changed climates. But the Devonian is notably the 'age of fishes,' and its waters, which covered much of Europe, swarmed with the ganoid type.

Coal is formed of compressed and chemically-altered plants, and occurs in all water-laid rocks, although in very different states and kinds. Professor Sachs remarks that every experiment on nutrition with green-leaved plants confirms the theory that their carbon is derived solely from the atmosphere, and we get some idea how enormously large that derivation has been on 'reflecting that the deposits of coal, lignite, and turf spread over the whole earth, and the bituminous substances as great or even greater in quantity which permeate mountain formations, besides asphalte, petroleum, &c., are products of the decomposition of earlier vegetations, which in the course of millions of years have taken from the atmosphere the carbon contained in these substances, and transformed it into organic substance.'

The climate and soil, during long eras of the *Carboniferous* system, specially favoured the growth of plants most fitted for coal formation. A large part of Europe (and the like conditions apply wherever the true coal measures abound) was then covered with shallow waters, both salt and fresh, divided by low ridges, bases of future mountain-chains, and dotted with islands; while numerous rivers traversed the land, and silted up lagoons and lakes with the *débris* worn from older rocks. Vegetation flourished apace on these river banks and marshy flats, and, with intermittent subsidence of the soil occurring again and again, was buried under sand and mud, becoming changed into coal of varying seams of thickness.

Of the plants forming the coal measures, the larger

number are obliterated, but they all belong to the lower orders, as do the club-mosses, tree-ferns, and other forms which, in the warm, moist atmosphere of those times, reached a gigantic size, and had a world-wide range far into north polar regions, where coal-seams have been found. Of the animal life that dwelt amongst them we know very little, nor do the extant fragments represent a tithe of the forms then flourishing. In the later deposits the lower sub-kingdoms are represented by spiders and large scorpions; by land-snails, beetles, cockroaches (the 'black beetles' of our kitchens), of which above eighty species occur, walking-stick insects a foot long, giant dragon-flies, and other insects. The first known land vertebrates appear in the salamander-like and long-extinct amphibians called labyrinthodonts, from the labyrinthine structure of their teeth, a structure found in some of the ganoids. The marine remains are still dominant. The lower types persist; the trilobites are on the verge of extinction, but higher forms of the same group, allied more nearly to the lobster and the shrimp, succeed. The first known oysters appear, and have survived all changes until now, spreading themselves over the whole northern hemisphere. Forerunners of the beautiful ammonites are found; and the fish, while still of the armoured species, have a more reptilian character than their Devonian ancestors.

The life-features of the *Permian* system, the last division of the Primary epoch, differ but little from those of the Carboniferous; the only, although im-

portant, distinction is in the remains of true reptiles with crocodile-like characters.

2. SECONDARY.—We now leave the Primary epoch and enter the Secondary epoch, with its widely different features and contents, explicable only by a great break in the succession of strata, and by an enormous lapse of time for the modification of the life-forms. Although, as in every period, volcanic action is manifest, the igneous rocks being pushed through the strata, or now and again alternating with them, we meet with few traces of the metamorphism which so baffles examination of the earlier rocks; we can mark more definitely the boundaries of land and water, measure more accurately the changes, and trace more clearly the relations between the successive life-forms, of which the marine are still the preponderating, and the reptilian the most marvellous.

In the earliest division of this epoch, the *Triassic*, many of the leading Palæozoic types are extinct. Several plants of the Coal and Permian systems have disappeared, and the flora consists mainly of ferns, of cycads or palm-ferns, and of conifers, to which the cycads are allied. Among the invertebrate animals certain molluscs are no longer found, but there is an intermingling of old and new types. Oysters and whelks and members of the cuttle-fish group are abundant. As yet fishes exhibit no marked advance in structure, and the labyrinthodonts, the time-range of which is thus shown to have been enormous, are changed only in size, as their human-hand-like footprints evidence. Reptiles allied to the crocodile

group, and sea-lizards, which attained gigantic size in later periods, are now the dominant types. Whether certain bipedal footprints in the Triassic sandstones are those of birds is doubtful; perhaps they are tracks of reptiles with bird-like movements. The Triassic system has yielded remains of the earliest known mammals, probably of the marsupial or pouched order, a form now represented most nearly by the Australian phalangers and the American opossums. It seems likely that at the stage when the Amphibian type was passing into the Reptilian, the Mammalian was in course of descent from the common ancestral life-tree.

The *Jurassic* or *Oolitic* system occupies extensive areas in both hemispheres, and ranges from the Arctic circle to Australia. Its strata, largely composed of coral growths and other organic remains, are rich in special life-forms which are limited to the Secondary epoch.

Its seas, which overspread the greater part of Europe, covering the large salt lakes of the Trias, swarmed with exquisite spiral ammonites, large and small; with conical bolt-like belemnites, allied to the cuttle-fish group; with lobsters, prawns, and crabs, which succeeded the trilobites and other crustaceans; with ganoid fishes, sharks, and rays. And 'there were giants in those days'—monsters stranger than any of which the old legends tell—in ferocious sea-lizards, with fish-like bodies and flipper-like limbs; monsters of the land, also, of dread aspect and size. Among the remains found in North American beds

are some belonging to a creature which must have been more than eighty feet in length, and, if it walked upon its hind limbs, above thirty feet in height. Another huge animal, whose back, from head to tail, bore a row of large triangular plates, had two sets of brains, one in its small skull, and the other near its haunches, the latter directing the movements of the hind limbs and tail. There were flying lizards, winged like bats, hollow-boned like birds, and with claws, skin, and teeth like reptiles; and it is in Jurassic limestone strata that remains of the oldest known true bird, a creature about the size of a rook, called archæopteryx (or 'ancient winged'), is found. It does not correspond to any known past or present birds, but represents a transitional type, having both bird- and reptile-like characters. In addition to free claws to each wing, the tail is long, and made up of separate bones or prolonged vertebræ, a feature noted in the embryos of birds. The remains of a bird about the size of a crane, but with uncertain affinities, have also been found in the Jurassic beds of Wyoming.

While the sea then, as ever, was the more thickly peopled, the land had a far more important air-breathing population, both of small things and great. The hum of insect life filled the forests, butterflies sported in the sunshine, spiders spread their webs for prey, and the remains of marsupials point to the range of these small but highly organised creatures over Western Europe. The plants and animals of the British Isles in Jurassic times probably resembled those still found in Australia, which, by reason of its

long isolation from other continents, has preserved in its pouched mammals, its mud-fish, and its cycads more ancient life-forms than any other country, perhaps New Zealand excepted.

The vast chalk formations of the globe are the typical features of the *Cretaceous* period, when the sea overspread a large part of Europe, Asia, and Northern Africa, receiving on its floor the foraminiferal shells which were converted into chalk, and the skeletons of sponges and other organisms round which silica has gathered, forming the flints which occur in limestones of all ages from the Silurian downwards. Molluscs, nautiluses, belemnites, ammonites, some of them the size of a cart-wheel, swarmed in its waters; and with them the huge reptiles of Jurassic times, sea-lizards and sea-serpents, also ganoids and sharks; and, what is important to note, bony-skeletoned fish allied to the salmon, herring, and perch families.

In the North American formations, which have so largely added to our knowledge of ancient life-forms, 'dragons of the prime,' crocodile-like, bird-like, and bat-like, are found; also toothed birds, with reptile-like brains, and the remains of true birds, these last being rare in the Old World. Little trace of the Cretaceous land-areas remains, but the plants of the upper strata resemble existing vegetation, or leaf-bearing trees having a true bark, and growing from the outside, with their seeds enclosed in a vessel. They are called 'exogens' in contrast to 'endogens,' or palms, grasses, and lilies, which have no true bark, and grow by additions from the inside.

Of the total thickness of the stratified rocks, estimated at about one hundred and ninety thousand feet, the Secondary systems occupy twenty-five thousand, or about one-eighth of the whole. But their importance, like that of later formations, is not to be measured by the space which they fill, since it is during their deposition, when, as the coal-seams and coral deposits of extreme northern zones show, warm climates prevailed, that the marked advance in specialisation of plant and animal forms is manifest.

3. TERTIARY.—Those warm climates continued far into the Tertiary epoch, but they were followed by declining temperatures, which at last resulted in the long and intermittent period of intense cold known as the Glacial epoch. Large areas of Europe and North America were then swathed in ice, which gouged and moulded the subsiding land, choking the sea with *débris*, and destroying numberless species of plants and animals, to the lasting biological impoverishment of after times. For when once a type is extinct, it never reappears. In the end the temperature gradually rose to its present level.

The Tertiary epoch marks the beginning of the present order of things, and of the existing distribution of land and sea, as also the uprising of most of the great mountain-chains.

Although much of the existing land-area was then submerged under shallow seas, the sites of the great continents of both hemispheres had well-nigh the same outlines as now. Varied as are the life-forms, they manifest a gradual approach to existing species

and a marked divergence from the species of older epochs. The colossal reptiles of Jurassic and Cretaceous times, the ammonites and other mollusca of their seas, are extinct. The age of huge reptiles has given place to the age of mammals, with their intermediate forms, but with no one group dominant, and with no important group unrepresented. Larger animals have always been less able to resist changes than smaller animals, which more readily adapt themselves to changed conditions; hence their long time-range compared with that of animals of unwieldy structure and small brains. And while the big reptiles of the Secondary epoch, like the big plants of the Carboniferous system, have left only dwarfed representatives, it is from the persistent smaller types that the higher mammals are descended.

The links between the Secondary and the Tertiary epochs are rarely represented by any known strata, denudation having swept away most of the intermediate deposits with their contents. And so confused are the Tertiary strata that their order in time is determined solely by the proportion of their shellfish to existing species, ranging from as low as three per cent. in the oldest beds to ninety-five per cent. in the newest. Mollusca have been called the alphabet of palæontology, because their extensive distribution through the several epochs renders them the most valuable and trustworthy of all organic remains in assigning the order in time and the conditions of life, not only of their own species, but of other species whose life-history is briefer, and whose range is more limited.

The rocks of the Tertiary epoch witness to wide-spread aqueous and volcanic action. This is specially noticeable in the *Eocene* strata, prominent among which are the vast beds of limestone laid down when Europe, its north-west corner excepted, and Central Asia were covered by the sea, Hindostan being an island. These beds extend from the Pyrenees to China and Japan, and also largely compose the Alps, Carpathians, Himalayas, Atlas, and lesser mountain-chains. Not many noble nor mighty are called to the enduring tasks of nature. It is the minute agents, unresting and wide-spread, that have been the efficient causes of much that is grandest in earth-structure; and it is of shells of the coin-like nummulites that these stupendous formations are mainly composed. Their foundations were laid in archæan times in the fissures opened in the crust by volcanic action. Into these fell the sediment and organic deposits of ancient seas, which ultimately, as the cooling crust caved in by its own weight upon the shrinking hot nucleus, were squeezed and puckered and overturned by lateral pressure into numberless folds; or plicated and bulged through the heat generated by the accumulation of sediment. Then, when the twisted and crumpled strata were upheaved above the sea-level, water and the powers of the air sculptured them into pinnacle and peak, into ravine and valley. So the big mountains, as we know them, are relatively modern; the lesser ones are the older, as longest subject to the wear and tear of eroding agents. During the greater part of the Secondary epoch the sea flowed where

the Alps now rise; Mont Blanc and the Matterhorn are not older than the Eocene marine clay on which London stands; and the Righi, a fresh-water shingle-bed, is younger still.

Broadly grouping the life of Eocene times, we find large whales, teleost or bony-skeletoned fish in abundance, and the persistent ganoids. Birds and bats are in the air; crocodiles and turtles swarm in the shallows; snakes and serpents make their appearance; the mammals are no longer restricted to pouch-bearers, for the placentals—huge quadrupeds, carnivora, hornless deer, and hog-like forms of a type between the tapir and the horse—appear in large numbers. Among the most remarkable fossils from North American beds are those of the ancestors of the horse, from creatures with three- and four-hoofed toes on each foot to the five-toed pigmy *Phenacodus*. A still more significant biological link is found in the lemuroids of the Upper Eocene (which belong to the Primates, or order of mammals including man and ape), possessing characters allying them to one or other of the hoofed quadrupeds then living. The plants, which were slowly dispersed over the northern hemisphere from polar regions, were tropical in character, as shown by remains in the Thames valley delta and corresponding deposits.

The like character applies to the flora of early *Miocene* (in which is included *Oligocene*) times, which are represented by only a patch or two of deposit in Britain. Timber trees, evergreens, and water-lilies flourished within eight degrees of the north pole, with

which Europe and America were connected by way of the Faroe Islands, Iceland, and Greenland, or of Behring Straits. The animals approximated more nearly to those of the present, save in the huge size of some of the mammals, as of the mastodon and other creatures allied to the elephant.

Small rhinoceroses, hornless deer, anthropoid apes as large as man, and, probably, the ape-like ancestors of man, if not man himself, as some think, appeared; the horse corresponded more nearly to his modern descendant, the variation being that each foot had three toes, of which only one touched the ground. Birds and insects were abundant; of the latter, thirteen hundred species have been found in Switzerland alone.

The *Pliocene* period ushered-in great local changes in land and water distribution. The lofty ridge, clothed with oaks and vines, that had stretched from France to Greenland, and the remnants of whose volcanic chain, of which Hecla is the sole active relic, are extant in the Hebrides and the Highlands of Scotland and Wales, was submerged. Europe was thus severed from America, but Britain was left as a peninsula, the newly invading waters of the North Sea dividing Scotland from Norway. On the other hand, the Eurasian continent was upraised in parts, leaving the deeper basins of the Black, the Aral, and the Caspian Seas as remnants of the shallow waters that had linked together the Baltic and the Persian Gulf, and also the Arctic and the Indian Oceans.

Except in the larger species, which gradually died out, the hippopotamus alone among them surviving to

this day, the quadrupeds varied little from those of the Miocene, the most remarkable being fierce sabre-toothed felines and large ruminants.

Pliocene fauna and flora alike witness to a cooling climate. The life-destroying agencies are at work; the cold fingers of the ice-giant are being spread over the northern hemisphere to the fiftieth parallel of latitude, dinting and rounding its surface, and leaving to this day the traces of their impress in the snow-fields and glaciers of Scandinavia and Switzerland. Glacial action swept away the northern flora, never to return, the existing vegetation being almost entirely post-glacial and of eastern origin.

4. Quaternary.—Upon the glacial deposits or boulder clays, only the most recent of which contain fossils, and these poor and scanty, rest the strata of the present geological epoch, the *Quaternary* or *Post-Tertiary*, or *Pleistocene*, as it is variously called. This is subdivided into the Post-Pliocene and the Recent, the former containing the remains of many extinct animals, as huge wingless birds and sloth-like mammals, and the latter the remains of none but existing species. The record here gains an interest for us that it could not possess before, because man now certainly appears on the scene. Some authorities contend that he lived in Europe before or during the Ice Age, but the evidence in support of this is not conclusive. The mammalian, tree-dwelling animals from whom man and the big apes are descended, had their origin in unknown regions in Tertiary times, but it is in Quaternary times in North-western Europe

that we have the earliest assured traces of man's presence, not so much in himself, since only the scantiest fragments of his fragile skeleton have been preserved, as in numerous tools and weapons of rudely chipped flint and other accessible materials which were fashioned like those found in use among savages all the world over.

The successive stages of man's advance from the period when he had become man in the full sense of the word, have been divided as follows:—

I. The Palæolithic or Ancient Stone Age, when roughly-worked flints and stones, and also bone, horn, and wood, were the materials used for tools and weapons. These are found, some in old river-gravels called the Drift, and others, of rather higher type, in limestone caverns (as Kent's Hole, Torquay), with bones of the woolly-haired elephant or mammoth and reindeer, on some of which rude pictures of the creatures themselves are scratched. Man was then in the hunting stage, living on roots and fruits, fish, and such beasts and birds as he could kill, and clothed in skins flung over him or sewn together with sinews by bone needles, his dwellings being caves and rocks or tree-shelters. The now extinct Tasmanians most nearly represented Palæolithic man's general state. Marked as are the differences, it is uncertain whether any complete break exists between the Palæolithic Age and

II. The Neolithic or Newer Stone Age, when man ground and polished his stone implements, hafting his axes and lances, &c., and showing skill in their shape, as in barbed arrowheads. Rustics called these 'elf-

darts' and used them as charms against the 'little folk.' Man had then approached a more settled state, partly as shepherd, partly as tiller of the soil, as evidenced in bones of domestic animals (the dog, earliest of all), and in seeds, cereals, &c., found in the Swiss lake-dwellings and elsewhere. Between this and succeeding ages there is no break.

III. The Age of Copper and Bronze, when the great start was made through the discovery of metals; copper first, and most easily worked of all, then the compound copper and tin, forming the harder metal bronze. Following this is

IV. The Age of Iron, when this most valuable of all the metals superseded the others as man's mighty weapon in his subdual of the earth.

These ages are not simultaneous. Certain races, as those of Southern Europe, had advanced to the use of metals when races of Northern Europe were in the stone-using stage. Neither is the sequence of the later ages universal, for some races, as in Africa and Polynesia, passed direct from the use of stone to that of iron through its introduction by white people.

In the foregoing rapid summary of the earth's past zoology and botany much of detail has been left out for clearer presentment of the typical features of each epoch, and of the scale of life as an ascending scale. The older the rock the simpler the life-forms.

The seaweed and the lichen, stemless and leafless, are lower than the club-moss and the tree-fern; these are lower than the true timber tree, with its com-

plex arrangement of trunk, branches, leaves, flowers, and fruit. The sponge, rooted plant-like to the rock, is lower than the coral or the star-fish; these, again, than crabs or shell-fish, the most highly organised of which are lower than the vertebrates, between the several groups of which the ascents are manifest in fish, reptile, bird, and mammal. And among these last there are the lesser and the greater: the pouch-bearers, bringing forth their young immature, are less specialised than the placentals, bringing forth their young fully developed; while here, also, the ascending grades are seen in whales, ungulates, carnivora, monkeys, men.

To all which the fossil-yielding rocks bring their witness. Imperfect as is their record, obscure as in certain cases are the causes of modification resulting in the appearance of new types, the evidence as to ascent of life from the simple to the complex, and as to its succession, is overwhelming. There was a time when the earth was devoid of life, and we are very far from its 'protoplast' beginnings in the earliest known organic remains, just as all species probably came into being long before we have any trace of them. But no evidence as to their first appearance that may be gathered from parts still unexplored is likely to alter the relative order assigned to the several types as compared with one another.

The history of the earth is written by fire and water: its life-history by water alone.

The volcanic and other modes of plutonic disturbance that have cracked and crumpled its crust are

due to the remaining store of energy within. But the more constant agents of change on the earth's surface have been the dissolving air and the eroding water. No sooner has land been upheaved above sea than these causes have begun their levelling work, and the *débris* have been again carried to the waters

TABLE OF THE SUCCESSIVE APPEARANCE OF TYPICAL LIFE-FORMS.

Epoch.	System.	Animal.	Plant.
ARCHÆAN or EOZOIC AND PRIMARY or PALÆOZOIC. (Earliest known Life-forms.)	Laurentian.	*Eozoon Canadense* (?); Foraminifera.	Seaweeds; club-mosses.
	Cambrian.	Sponges; corals; crustacea; shell-fish.	
	Silurian.	Huge crustacea; the lowest known vertebrates (ganoids or armoured *fish*).	
(Age of Ferns and Fishes.)	Devonian.	Insects; swarms of ganoids.	Ferns; calamites; cycads.
	Carboniferous.	Land vertebrates (labyrinthodonts).	
	Permian.	*Reptiles.*	
SECONDARY or MESOZOIC.	Triassic.	Immense reptiles; sea-lizards; *marsupial mammals.*	Conifers; palms.
(Age of Pines and Reptiles.)	Jurassic.	Immense bird-reptiles; true *birds.*	
	Cretaceous.	Bony-skeletoned fish; large ammonites.	
	(Laramie intervening.)		
TERTIARY or CAINOZOIC.	Eocene.	Huge *placental mammals*; serpents; nummulites.	Trees, shrubs, herbs allied to existing sub-tropical species.
(Age of Leaf-forests and Mammals.)	Miocene and Pliocene.	True whales; man-like apes.	
(Glacial epoch intervening, and continuing into the—)			
QUATERNARY.	Post-Pliocene.	Mammoth and other woolly quadrupeds; *man.*	Arctic and temperate.
	Recent or Historic.	Existing species.	Existing species.

to form new continents. And thus it is that between the opposing agents of waste and repair, of upheaval and subsidence, with the ceaseless interplay of life in growth and decay, as in the polyps that build the coral reefs and the plants that form the coal-beds, and not least among them now the action of man himself on nature, this ancient earth is maintained from age to age, mother of all living.

CHAPTER V.

PRESENT LIFE-FORMS.

I. PLANTS.

Sea and other water-weeds (*Algæ*) . . . . . Fungi . . . . . Lichens	Gymnospores, *i.e.*, naked spores.
Mosses . . . . . Ferns and Horsetails . . Club-mosses	Angiospores, *i.e.*, enclosed spores.
Pines and Palm Ferns . . (Many seed-lobes.)	Gymnosperms, *i.e.*, naked seeds.
Grasses, Sedges, Palms . . (One seed-lobe.) Trees, Shrubs, Herbs . . (Two seed-lobes.)	Angiosperms, *i.e.*, enclosed seeds.

II. ANIMALS.

1. Invertebrates, *i.e.*, without backbone :

Monera (Gr. *monos*, single) .	Structureless, sticky, alike all over.
Amœbæ (Gr. *amoibe*, change)	Slight unlikeness of parts ; always changing shape.
Foraminifera (Lat. *foramen*, an opening)	Secrete shell or skeleton of lime from water. Show passage to further unlikeness in parts.
Polycystina (Gr. *polus*, many ; and *kustis*, a cyst) . .	Secrete shell or skeleton of flint from water.

Sponges.

Coral animals, anemones, jelly-fish. No fossils of these soft-bodied lowest forms exist.

Sea-lilies, star-fish.

Worms of all kinds . . . Crabs, spiders, centipedes, insects.	Annelida and Arthropoda.
Oysters, snails, cuttle-fish. .	Mollusca.

Connecting links between Invertebrates and Vertebrates : Balanoglossus : Sea-squirt ; Lancelet.

2. VERTEBRATES :

A. *Pisces.*
Fish of all kinds.

B. *Amphibia.*
Toad, frog.

C. *Reptilia.*
Serpent, lizard, crocodile, turtle.

D. *Aves.*
Birds of all kinds.

E. *Mammalia.*

1. Aplacental (bringing forth immature young) :—*Monotremes*, or one-vented : duckbill, spiny ant-eater. *Marsupials*, or pouched : kangaroo, opossum.

2. Placental (bringing forth mature young) : —Ant-eater, sloth, manatee ; whales and porpoises ; horse and all other hoofed animals ; elephant ; seal, dog, lion, tiger, and all other flesh-feeders ; hare and all other gnawing animals ; bats ; moles and all other insect-feeders ; apes ; man.

ALL THINGS THE WORLD WHICH FILL
OF BUT ONE STUFF ARE SPUN,

and this stuff, the basis of all life, the formative power, 'universally known and yet essentially unknown,' to which the name protoplasm (Gr. *protos*, first ; *plasma*, moulded) has been given, is a semi-fluid, sticky material, full of numberless minute granules in ceaseless and rapid motion. 'It is not a compound, but a structure built up of compounds, consisting of the

elementary substances carbon, hydrogen, oxygen, and nitrogen, in very complex union.' They are the *essential* elements, but a few others enter into the chemistry of life, with resulting slight differences in the *incidental* elements in animals and plants. Moreover, a fundamental unity of form and of function underlies and pervades living matter, from the slime of a stagnant ditch to the most complex animal; the differences between living things being in degree, and not in kind.

In the old division of the three kingdoms of nature into the mineral, the vegetable, and the animal, we were taught that stones grow; that plants grow and live; while animals grow, live, and move. But this no longer holds good, at least in respect of the lower life-forms. There are plants, as diatoms and desmids, which are locomotive throughout life; there are animals, as sponges and corals, which are rooted to the spot where they grow; and there are organisms which appear to be plants at one stage of their growth and animals at another stage.

Other marks of supposed unlikeness have vanished. It was formerly held that among the distinctive features of animals are—(1) a sac or cavity in which to receive and digest food; (2) the power to absorb oxygen and exhale carbonic acid; and (3) a nervous system. But although nearly all animals, in virtue of their food being solid, have a mouth and an alimentary cavity, the lowest forms are without these organs; and although plants, in virtue of their food being liquid or gaseous, need not that cavity, there are

some that have it. Not only is the process of digestion apparent in the leaves of carnivorous plants, the hair-like glands on which contain pepsin, but embryonic forms have been found to secrete a ferment similar to the ferment in the pancreatic secretion of animals, by which they dissolve and utilise the food-stores in their seed-lobes as completely as food is digested in our stomachs. And although green plants, under the action of light, break up carbonic acid and release the oxygen, they do the reverse in the dark, as also in respiration; while the quasi-animal fungi which are independent of light absorb oxygen and give off carbonic acid.

In the 'irritability' of the sundew, Venus's fly-trap, and other sensitive plants, still more so in subtile and hidden movements in plant-cells, we have actions corresponding to those called 'reflex' in animals, as the contraction of the shapeless amœba when touched, or the involuntary closing of one's eyelid when the eye is threatened, or the drawing back of one's feet when tickled.

In these and kindred vital processes, in the so-called sleep-movements of leaves and flowers, both regulated by the amount of light, apparently acting on them as it acts on our nervous system; in the detection of subtile differences in light which escape the human eye, by plants; in the higher range of sensation which they manifest, as compared to some animals; in their choice of food, and of the material of the covering which some of them secrete; in their general sensitiveness to external influences; even in

the diseases which attack them; we have the rudiments of attributes and powers which reach their full development in the higher animals, and therefore a series of fundamental correspondences between plant and animal which point to the merging of their apparent differences in one community of origin.

In fine, that which was once thought special to one is now found to be common to both, and to this there is no exception. Not only is there correspondence in external form in the lower life-groups, but, fundamentally, plants and animals are alike in internal structure, and in the discharge of the mysterious processes of reproduction and of nutrition, although this last forms a convenient line of separation.

For the plant possesses the power of weaving the visible out of the invisible, of converting the lifeless into the living. This it does by virtue of the green colouring matter called chlorophyll, which is found united with definite portions of the protoplasm mass, of which it is a modification, the exact nature being unknown. The water supplied by the root, and the carbonic acid which the plant absorbs through the numberless stomata or mouth-pores in its leaves or integuments are, when the sunlight falls upon them, broken up by the chlorophyll, which sets free the oxygen, and locks together the hydrogen and carbon, converting this hydrocarbon into the simple and complex cells and tissues of the plant, with their store of energy for service to itself and to other organisms. Animals cannot do this; they are power-

less to convert water, salts, gases, or any other inorganic substances into organic: they are able only to assimilate the matter thus supplied by the plant, nourishing themselves therewith, either directly, by eating the plant; or indirectly, by eating some plant-feeding animal. In other words, the plant manufactures protein from the mineral world, and the animal obtains the protein ready made; the plant converts the simple into the complex, and this the animal, by combining it with oxygen, consumes, using up the energy which it thereby obtains in doing work. So the plant is the origin of all the energy possessed by living things; but how it can convert the stable inorganic into the unstable organic, while the animal cannot, we do not know.

Structurally, the lowest animal is below the lowest plant, since it is a speck of relatively formless, colourless protoplasm, whereas the protoplasm of the lowest plant is visibly organised to the extent that it has formed for itself an outer layer or membranous coat called the cell-wall. But the plant sealed its lower fate thereby, because it became less accessible to external influences, less able to combine for the construction of nervous and muscular tissues, than animals, and condemned to an automatic life. While the animal remained free to wander, and developed organs of digestion and motion, the plant, being fixed, perforce struck its tentacles into the soil for foothold, and developed a large surface of green leaf to take in the food which the wind and the water brought it. In changing the substance of its cell

wall into woody tissue it prevented the evaporation of the food-carrying fluids, and gained that solidity and form of which man has availed himself in the use of timber for the needs and arts of life.

As the function—in other words, the work which it has to do—creates the organ, and as where a function is not performed by a special organ there is no variation of parts, life probably began in combinations having no visible distinction of parts. And as the cell is the first step in visible organisation, it is the fundamental structure of living things. The lowest organisms consist of one *cell* only, and the higher consist of many cells, which, increasing in complexity or diversity of form adapted to their different functions at later stages, are modified into the special *tissues*, with resulting unlikeness in parts or *organs*, of which all higher plants and animals are composed. Every variation in structure is therefore due to cellular changes, and every living thing is propagated in one way or another by cells; by their self-division or fission; or by gemmation, *i.e.*, throwing off buds; or by the union of like cells; or in more complex mode, by the spontaneous or aided union of unlike cells, as the sperm-cell of the male with the germ-cell of the female, giving rise to a seed or egg from which grows offspring more or less like its parents.

In both plant and animal the cell contents—although here again exceptions occur in some of the lowest organisms,—exhibit a rounded body called the *nucleus* (in large cells there are many *nuclei*), which

itself often encloses another body called the *nucleolus*, but the functions performed by both in cell development are obscure. That even this much is known of cell structure may awaken wonder when it is remembered that we are dealing with bodies for the most part beyond the range of our unaided vision. But size counts for little: the oak and pine, the acacia and the rose, are lower in the scale of life than the thistle and the daisy; the elephant is one hundred and fifty thousand times heavier than the mouse, but the egg of the one is nearly as large as that of the other; and it has been calculated that if one molecule in the *nucleus* of the ovum of a mammal were to be lost in every second of time, the whole would not be exhausted in seventeen years.

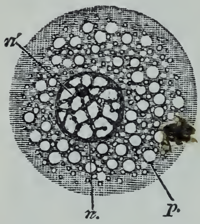


DIAGRAM OF A CELL.

p, protoplasm; *n*, nucleus; *n'*, nucleolus.

These molecules are the vehicles of transmission of resemblances, both of body and mind, between parent and offspring; and of the vast sum-total of inherited tendencies, good or bad, which are the product of no one generation, but which reach us charged with the gathered force of countless ancestral experiences.

> Born into life, man grows
> Forth from his parents' stem,
> And blends their bloods, as those
> Of theirs are blent in them;
> So each new man strikes root into a far foretime.

A. *Plants.*

Plants are divided into two main groups or subkingdoms: I. Cryptogams (Gr. *kruptos*, hidden; *gamos*, marriage), or flowerless. II. Phanerogams (Gr. *phaneros*, open; *gamos*, marriage), or flowering.

I. The *Cryptogams* are subdivided into—

1. Thallophytes (Gr. *thallos*, a shoot; *phyton*, a plant), comprising algæ, fungi, and lichens. These have no leaves, stems, or roots; many of them are one-celled.

2. Bryophytes (Gr. *bryon*, moss), comprising mosses and liverworts. These have leaves and stems, but no true roots.

3. Pteridophytes (Gr. *pteris*, a fern), comprising ferns, horsetails, and club-mosses. These have stems, leaves, and roots.

The feature common to the cryptogams is the absence of any conspicuous organs, *i.e.*, true flowers, with stamens and pistils for the production of seeds or fruits. The simplest or single-celled plants increase by subdivision, each cell carrying on an independent life and repeating the process of division. But sexuality is manifest in plants very low down in the scale, the mode of reproduction varying a good deal in different species. In some cryptogams it is almost as complex as in the flowering plants; but notwithstanding the different kinds of sexual organs, there is this fundamental resemblance between them,

that the union of the contents of two cells, a male or sperm cell, and a female or germ cell, each of which is by itself incapable of further development, is essential to the production of the embryo or seed.

The lowest cryptogams are congregations of simple fibreless cells united in rows, or gathered round one another, and spreading on all sides. At the bottom of the scale are the *Algæ*, comprising some ten thousand species, from the microscopic fresh-water desmids, one-millionth of an inch in length, with their whip-like cilia the two hundred millionth of an inch long, to the giant seaweeds or tangles, hundreds of feet in length, that cover thousands of square miles of ocean. Like the foraminifera and other low animal organisms, they illustrate the persistency of the earlier forms, in virtue of their simplicity of structure, despite changing conditions.

Next to the algæ in ascending order are those fantastic products of decay, the quick-growing, short-lived *Fungi*, animal-like in their mode of nutrition, plant-like in their fixity, and through untold epochs the agents by which dead plants and animals are resolved into the inorganic, and made available to enter into new combinations. Next in order are the *Lichens*, which, it is now generally agreed, are composite plants, being a special kind of parasitic fungi growing on algæ.

In *Mosses*, the cells have become developed into rudimentary root, stem, and leaf, manifesting still further transition towards unlikeness in parts which is due to division of function. But the structure is

still cellular, *i.e.*, there are no tissues and fibres. The mosses represent the intermediate forms between the lowest and the highest cryptogams, between the green algæ, out of which liverworts were probably developed, and ferns, which arose out of liverworts.

In *Ferns* the larger number of cells have joined together to form fibrous vessels, lengthening or thickening in varying shape and texture according to the functions to be discharged by them, resulting in the woody tissue which enters into the structure of all the higher plants.

The ferns and club-mosses and horsetails of the present day are the puny representatives of the stately and luxuriant, although sombre, flowerless trees that composed the dense jungles of green vegetation in the Devonian and succeeding Primary periods, during which our fossil fuel was chiefly formed. The existing palm-like vegetation of the tropics more nearly approaches its Devonian prototype, but it falls far behind it in abundance as well as in size.

II. The *Phanerogams* have their flowers with stamens and pistils conspicuous, and are divided, according to the formation of their seeds, into—

1. Gymnosperms, or naked-seeded, the ovum not being enclosed within a seed-vessel or ovary, but carried upon a cone, as in pines and allied species. The gymnosperms are the connecting link between the flowerless and the flowering plants.

2. Angiosperms, or cover-seeded, the ovum being enclosed within an ovary.

This group is subdivided into (*a*) plants having

one cotyledon or seed-leaf, from which they are developed, as palms, lilies, orchids, and grasses; and (*b*) plants having two seed-leaves, as oaks, beeches, and all trees and shrubs not included in the foregoing.

In naked-seeded plants the pollen or male element falls on the exposed ova; in cover-seeded plants it falls on the stigma, passes down the pistil into the seed-vessel, and enters the ovum through an opening in it called the micropyle, or 'little gate.'

Whilst the gymnosperms are, on the one hand, most nearly allied in the order of descent to ferns, the sombre flowers which they bear giving them only by strict botanical classification a place among phanerogams, they are, on the other hand, more complex in structure than the single seed-leaf plants, because their bark, wood, and pith are clearly defined, as in the double seed-leaf plants. Their lowest representatives comprise the cycads or palm-ferns, so called from their resemblance to palms, for which, with their crown of feathery leaves, they are often mistaken.

Next in order is the much more varied and widely distributed conifer family, notably pines, firs, and larches, and, lesser in importance, cedars and cypresses. A still higher class, various in its modes of growth, marks the transition to angiosperms, the flowers of both having many features in common.

The single seed-leaf angiosperms have no visible separation of their woody stuff into bark, stem, and pith, and have no rings of growth, the wood exhibit-

ing an even surface, dotted over with small dark points. Their leaves have parallel veins or 'nerves,' as in the onion and tulip; and the blossom-leaves, or petals, are most usually grouped in threes or multiples of three. Among their several representatives we may single out the lilies for their beauty and fragrance, and the cereals for their value and importance, both classes being in near connection, since the grasses from which man has developed wheat, barley, oats, rice, and maize are, in a botanical sense, degenerate descendants of the lily family.

The double seed-leaf plants include all the highest and most specialised varieties. Bark, stem, pith, and concentric rings of growth by which the age of the plants may, in some species, be reckoned, are clearly defined; the leaves are netted-veined, and the petals are most usually grouped in fours or fives or multiples of those numbers. The lowest class, represented by the catkin-bearers, as the birch and alder, the poplar and the oak, and by plants allied to the nettle and to the laurel, are nearly related to the highest gymnosperms. Next in order are the crown-bearers, or flowers with corollas, as the rose family, which includes most of our fruit-yielders, from strawberries to apples; while the highest and most perfect of all are plants in which the petals are united together in bell shape or funnel fashion. Such are the convolvulus and honeysuckle, the olive and ash, and, at the top of the plant-scale, the family of which the daisy is the most familiar representative. Its position among plants corresponds to man's position among

animals. As he, in virtue of being the most complex and highly specialised, is at their head, albeit many exceed him in bulk and strength, so is the daisy with its allies, for like reasons, above the giants of the forest.

The primary function for which the organs of plants known as flowers exist is not that which man has long assumed. He once thought that the earth was the centre of the universe, until astronomy dispelled the illusion ; and there yet lingers in him an old Adam of conceit that everything on the earth has for its sole end and aim his advantage and service. Evolution will dispel *that* illusion. But our delight in the colours and perfumes of flowers will not be lessened, while wonder will have larger field for play, in learning that the coloured leaves known as flowers, together with their scent and honey, have been developed in furtherance of nature's supreme aim—the perpetuation of the species. For that alone the flowers blossom and the fruits ripen. And truly the contrivances to secure this which are manifest in plant-life are astounding, even to those who perceive most clearly the unity of function which connects the highest and lowest life-forms together. It is difficult to deny the existence of a rudimentary consciousness in the efforts of certain plants to secure fertilisation. For example, in a well-known aquatic plant, *Vallisneria spiralis*, the male flower with its matured pollen is detached from the stem and rises to the surface, where, as it floats, it comes into contact with and fertilises the ovary of the female flower, whose stalks

then contract and carry the ovary to the bottom, where the seeds can ripen in safety. Most flowers are hermaphrodite, *i.e.*, have their male and female organs within the same petals, and in some cases fertilise themselves by scattering the pollen from the bursting stamens on the stigma or head of the pistil. But the most effective mode of reproduction is that in which two individuals are concerned. All organisms in which the sexes are separate have descended through many gradations from hermaphrodite ancestors, and it is to this division of function between male and female that not only a more vigorous offspring, but also progress among the higher animals, is, in the first instance, due. Were there no sex, there would be no social instincts, no love, no dependence, no unity.

Two agencies are unwittingly concerned in the fertilisation of plants—insects, and the wind; while in the dispersion of the matured seed, birds and other animals, and again the wind, play an important part.

Plants which are wind-fertilised have no gaily coloured petals or sepals, and do not secrete nectar. Such are the naked-seeded groups whose sombre flowers are borne on dull brown cones; and, among cover-seeded groups, grasses and rushes with their feathery flowers, and willows and birches with their long waving clusters of catkins. All of these provide against the fitfulness of the wind, which is as likely to blow pollen one way as another, by producing it in large quantities, so that it sometimes falls in thick showers, covering wide areas.

Plants which are insect-fertilised attract their visitors by secreting honey and developing coloured floral organs. The way in which this came about is probably as follows.

The common idea about flowers is that they are made up of petals and sepals, whereas the *essential* parts are the stamens and pistils, *i.e.*, the male or pollen-producing organs, and the female or seed-containing organs. The earliest flowers consisted of these alone, having no coloured whorl of petals within another coloured whorl of sepals, and were only scantily protected by leaves, as are many extant species. These the food-seeking insects then, as now, visited for the sake of the pollen, to the detriment of the plant, which lost the fertilising stuff and gained nothing in return. Besides the pollen, most plants secreted the sweet juice called honey, especially when in the act of flowering, for the nourishment of the blossom. This juice was often stored in nectaries near the seed-vessels, where the insects could not get at it without covering their bodies with some of the pollen, which they unknowingly rubbed on the pistils of the plant next visited, and thus fertilised the ovum, provided that the plants were nearly related. Honey being sweeter to the taste than pollen, the plants that produced most honey stood the better chance of repeated visits from insects, and therefore of fertilisation, to the manifest advantage of their species over others. Thus, as first shown by Conrad Sprengel in 1794, there were developed in the course of long ages intimate relations between the two, and

also marvellous contrivances to secure the visits of welcome insects of a certain form and size, and to prevent the intrusion of unwelcome insects, as well as to arrest the washing out of pollen by rain or dew. For as most plants are rooted to one spot, they cannot act on the aggressive. They have to develop defensive structures to resist attacks of devouring enemies; hence their thorns, prickles, spikes, sticky hairs, hooked fruits, nauseous taste, and other protective characters. Some plants have an eel-trap sort of arrangement of the hairs at the base of their petals, to retain the honey-seeker till the pollen is rubbed on it, when the hairs relax and release it. Others have become specially adapted to receive visits from certain insects by secreting the honey at the bottom of a tube (which is nearly a foot long in some orchids) and the insect has developed a proboscis long enough to reach it. The one aim of all these modifications of structure is to economise the pollen, and ensure its use for fertilisation to the advantage of its producer in the struggle for life. Still more were any plants advantaged on which spots or patches of colour appeared, attracting the eye of the insect, and developing through its agency into the tinted petals and sepals which have changed the earth's once flowerless meadows into fields of cloth of gold.

All growth involves expenditure of the energy which the plant has stored within itself, and which becomes active when the hydrocarbons combine with oxygen, resulting in cellular change, and appearance of other colours than the green of the chlorophyll.

Thus may be explained the colour of sprouting buds and young shoots, the more or less intensified colours of leaves and flowers, and the lovely tints of autumn; one and all being due to oxidation, the minutest changes inducing subtile variations in colour. As the stamens of most flowers are yellow, the earliest flowers, being derived from stamens, were probably yellow also; and all subsequent changes in colour take place in a regular order, yellow passing into white or pink, and then through red and purple into blue, but never in a reverse direction nor in any other order.

Whichever plants made most show of colour would the sooner catch the eye of insects, however dim their perception of the difference in colours might be, and would thus get fertilised before plants which made less display. Thus have insects been the main cause in the propagation of flowering plants, the plants in return developing the colour sense in insects. The flower nourishes the insect; the insect propagates the flower. Other contrivances to meet the need for fertilisation might be cited, as markings upon the petals to guide the insect to the nectary; the exhalation of scent by inconspicuous flowers, as mignonette; or by such as would attract visitors at night, as the night-smelling stock; but enough has been adduced to show that the chief, if not the sole function of flowers is to attract insects, and thus secure cross-fertilisation. Nor does the provision stop here. The fertilised seed is not left to chance, but, like the fertilising pollen, is entrusted to secondary agents, to the care of the birds and the breezes. Where not

scattered by the bursting of the ovary it is winged with gossamer shafts, as in the thistle and the dandelion, and floated on gentlest zephyr or rushing storm to a genial soil. Such wind-wafted seeds, like wind-fertilised flowers, are rarely coloured ; neither are the seeds of the larger trees, since their abundance ensures notice by food-seeking animals ; nor the nuts, which are protected by shelly coats. But other seeds enwrap themselves in sweet pulpy masses, called fruits, whose skins brighten as they ripen, and attract the eye of fruit-loving birds and beasts. The seeds pass through their stomachs undigested, and are scattered by them in their flight over wide areas. As with the brightest hued and sweetest scented flowers, so it is with the brightest and juiciest fruits ; they sooner attract the visitors whose services they need, and thus gain advantage over less favoured members of their species, developing by the selective action of their devourers into the finest and pulpiest kinds. And, as Grant Allen shows in his delightful and exhaustive book on the colour sense, the origin and development of this sense in the sub-kingdom which includes man is due to the same cause, man being descended from a fruit-eating animal 'who shared the common vertebrate faculty of colour perception and the common frugivorous taste for bright hues.' The subject is of course closely connected with the evolution of the sense of beauty, which, at first evoked by things connected with physical needs, was developed by leisurely contemplation of natural forms, colours, and groupings.

B. *Animals.*

All animals fall into two main groups: the structureless, or one-celled, called Protozoa; and the many-celled, called Metozoa.

The several types upon which they are constructed are usually classed under the following primary divisions, called sub-kingdoms:—

Invertebrata.	Protozoa (Gr. *protos*, first; *zoon*, animal).	Simplest forms.	*Ex.* Moneron, amœba.
	Cœlenterata (Gr. *koilos*, hollow; *enteron*, bowel).	Hollow-bodied.	*Ex.* Sponge, polyp, anemone, coral-builder.
	Echinodermata (Gr. *echinos*, a hedgehog; *derma*, skin).	Spiny-bodied.	*Ex.* Sea-urchin, star fish.
	Annelida (Lat. *annulus*, a ring); and Arthropoda (jointed-footed).	Joint-bodied.	*Ex.* Worm, crab, spider, ant.
	Mollusca (Lat. *mollis*, soft).	Soft-bodied (but usually protected by a shell).	*Ex.* Oyster, snail, cuttle-fish.
	Vertebrata (Lat. *vertebra*, a joint).	Back-boned.	*Ex.* Fish, and all other higher life-forms to man.

Tabular forms are convenient for clear presentment, but their hard and fast divisions are apt to be mistaken for real lines of separation, whereas the several sub-kingdoms merge one into the other, like the colours of the rainbow. As further reducing the number of types, animals may be divided into three grades: the Protozoa, which have no body cavity; the Cœlente-

rata, which have a body cavity; and the Cœlomata, including all animals, from echinoderms to man, which have a digestive cavity separate from the body cavity. Any consecutive arrangement can only broadly indicate the relative order of the several life-forms, because development has not proceeded in direct line—*e.g.*, the ant, which belongs to the Arthropoda, is the highest of all invertebrates; but it is not therefore most nearly allied to the lowest vertebrate. As will be shown later on, the connecting link between invertebrates and vertebrates is to be found in such animals as the worm-like Balanoglossus; the bottle-shaped sea-squirt or Ascidian (Gr. *askidion*, a little bottle); and the headless lancelet. If we go back far enough we find the common starting-point of all, whence they travelled for a while along the same road, and then diverged wider and wider apart, until it now seems difficult to believe that the lowest and highest, both of plant and animal, are one in community of origin.

1. *Protozoa.*

The lowest member of this group—in other words, the lowest known animal, if we except certain parasites—is the *moneron* (Gr. *monos*, single). Like the lowest plants, it lives in water, the element in which life had beginning. It is an extremely minute, shapeless, colourless, slimy mass, alike all over, and therefore without any organs. When we say that it is alike all over we mean that our range of vision

does not enable us to report otherwise, for doubtless the simplest and smallest living thing is very complex in structure. And we mean, further, that there is no differentiation, as it is called, *i.e.*, no formation of specific organs for the performance of specific functions. The functions of living things are threefold—nutrition, reproduction, and relation; in other words, to feed, to multiply, to respond to the outer world; and all these the organless moneron discharges. Every part of it does everything; it takes in food and oxygen anywhere, and digests and breathes all over its body.

Reference has been made to the response to stimulus from external things manifested by the lowest life-forms, although there is no trace of a nervous system in them; and now that we are treating of a living mass that not only feeds and digests and breathes all over, but likewise feels all over, a few remarks upon the function and origin of nerves may supersede the need of any detailed account of the several nervous systems in the representative animal types.

The function of the nerves is to bring the organism into relation with its surroundings; they are the special media of communication between the body and the external world, and between the brain and every movement of the parts of the body. Starting in the higher animals from the encased brain and ensheathed spinal cord, and diffused in the lower animals in less complex arrangement, they report from without to within. The vibrations of the ethereal medium that affect us as light enter the eye and pass along the optic nerve,

which conveys the impulse to the brain, and it is the brain, not the eye, that sees. So with the air-vibrations that travel along the aural nerves, the sensation of sound resides in the brain, not in the ear; so with all the manifold sensations that we feel. The unity of the sensations is fundamental; the differences lie in the vibrations.

Now, as every part of an organism is made up of cells, and as the functions govern the form of the cells, the origin of nerves must be due to a modification in cell shape and arrangement.

But what excited this modification? The all-surrounding medium, without which no life had been, which determined its forms and limits, and *touches* it at every point with its throbs and vibrations. In the beginnings of a primitive layer or skin exhibited by creatures a stage above the moneron, unlikenesses would arise, and certain parts would by reason of their finer structure be the more readily stimulated by, and the more quickly responsive to, the ceaseless action of the surroundings, the result being that an extra sensitiveness along the lines of least resistance would be set up in those more delicate parts. These would become more and more the selected paths of the impulses, leading, as the molecular waves thrilled them, to structural changes or modification into nerve-cells and nerve-fibres of ever-increasing complexity as we ascend the scale of life. The entire nervous system with its connections; the brain and all the subtile mechanism with which it controls the body; the organs of sense, with their mysterious se-

lective power — the olfactory organs, probably the earliest developed, so acute in man as to detect the presence of the one-three-billionth of a grain of mercaptan (sulphuretted alcohol), and yet coarse by comparison with the antennæ of insects, and the olfactory organs of creatures like the dog, to whom the world is made up of smells; the eye, to receive and sift vibrations travelling twelve million miles in a minute; the ear, with its eighteen thousand strings of Corti, each vibrating in response to a particular sound-wave; the organs of taste, guarding the entrance to the digestive canal and refusing admittance to contraband food—alike begin as sacs formed by infoldings of the primitive outer skin.

Development by cell-modification applies to the body throughout—to bone, to cartilage, and sinew, as well as to the myriads of nerve-tissues, varying between the fifteen-hundredth and the twelve-thousandth of an inch in breadth, that keep us in touch with the universe. But, easy as it is to dissect and describe the nervous mechanism, the nature of the connection alike between nervous impulse and consciousness in a man, and between sensation and contractile action in a moneron, remains an insoluble mystery.

A short step upward from the moneron brings us to the *Amœba*, so-called from its constant change of shape as it protrudes and withdraws the pseudopods or false feet by which both it and the moneron propel themselves. It shows approach towards unlikeness in parts in the modification of the protoplasm into a

membranous skin at the surface, and in a nucleus near the centre, with an expanding and contracting cavity for distributing food and oxygen in the body —a primitive apparatus for digestion and circulation. Therein the beginning of a distribution of labour, leading to cell-modification into organs, is illustrated.

Still more marked advance toward unlikeness in parts is shown in the *Infusoria,* so called because readily developed in infusions of exposed vegetable matter, where they crowd by myriads in the space of a water-drop. Instead of pseudopods we find vibrating filaments or cilia, by which supplies are swept into the body. This is furnished with a rudimentary mouth and short gullet, through which the food and oxygen pass to the body-cavity.

2. *Cœlenterata.*

The 'hollow-bodied' animals are made up of two layers of cells more or less modified. But they are still of low organisation, having no vital parts, and no separate canal for absorbing food and carrying away refuse, the mouth still opening direct into the body-cavity.

The lowest members of this sub-kingdom are the *Sponges.* They were long regarded as colonies of amœbæ; but fuller knowledge of their structure as many-celled organisms, some of the highest among which show slight traces of nerves and sense-organs, has caused them to be ranked in a division called Porifera (Lat. *porus*, a pore; and *fero*, to bear).

Very lovely are the skeletons which some of them secrete, such as Venus's flower-basket, with its graceful fretted spirals; but more familiar to us are the useful fibrous and porous domestic sponges, woven of material said to be chemically allied to that spun by silkworms. Being rooted to one spot, the sponge-cells have become specially modified for ingathering food and oxygen. Only the cells on the outside of the horny or flinty skeleton can procure these easily; those living inside effect their supply by means of cilia. The whip-like action of these drives the water, charged with food and oxygen, through the innumerable canals, whence, having served its purpose, it is driven out through other canals, carrying the refuse of the colony with it.

Next in rank above the sponges are the tiny cup or tube-shaped, jelly-like, green-hued (because chlorophyll-containing) polyps named *Hydra*, colonies of which, with their bud-like clusters of young—soon to start in life on their own account—are found clinging mouth downwards to weeds and rubbish in fresh water. From the mouth hang a number of tentacles containing cells, in which lie barbed threads coiled up in a poison-fluid. When anything touches these tentacles they contract, the cells burst and fling the thread, lasso-like, around the prey, poisoning it with the fluid. From some of the marine species which secrete tubes of flint, and project themselves therefrom like flowers, the buds detach themselves and become the beautifully tinted *Medusæ* or *jelly-fish*. These produce eggs which become rooted polyps, so that the

offspring never resembles its parents, but always its grandparents. All living matter is largely made up of water, the average proportion ranging from seventy to ninety per cent., but in the jelly-fish it is about four hundred to one. Yet, fragile as is the creature, its structure is complex. Canals traverse the swimming-bell, and carry food and oxygen to every part; rudimentary muscles in the shape of contractile tissues propel the animal along in rhythmic grace of motion; a nervous system runs round the margin of the bell; there are rudimentary eyes in bead-like pigment-spots, and rudimentary ears in small sacs along the margin; and the hanging tentacles are charged, as in its fresh-water ally, with deadly fluid.

Lovelier still, and of slightly more complex structure are the variously coloured *Sea-anemones*, with their petal-like tentacles; while nearly allied to these are the colonies of *Coral-builders*, which, despite the surging wave and drifting current, raise their tree-like structures on submarine foundations, bases of the land on which the bird builds her nest and man sets his dwelling.

3. *Echinodermata.*

This division includes all rayed animals, the skin being hardened by the secretion of jointed or leathery plates, or of spines or hedgehog-like prickles. In some, as the *Star-fish*, the rays spring from a common centre; in others, as the *Sea-urchin*, they are coiled to form a globular body; in the *Sea-lilies*, which abounded as far back as Silurian times, but

which are now limited in range, they spring, flower-like, from the end of a fixed stalk; in the slug-like *Sea-cucumbers*, which possess the power dyspeptics may envy of throwing away the inside of the body and growing it anew; the skin is tough, the limy matter being secreted in scattered spicules.

The echinoderms show marked advance towards unlikeness of parts in having a digestive canal shut off from the body-cavity, affording special provision for nutrition. This is effected by a number of canals which communicate with the outside of the body, and through which the sea-water is driven by cilia, as in the sponges. The water is also pressed from the canals into numerous little suckers, by which the animal crawls along—nature's first essay in locomotion on solid ground. There is a distinct nervous system, the fibres of which in the star-fish run along each ray, at the tip of which is an eye having about two hundred crystal lenses, and a primitive eyelid in the form of a filmy covering.

Thus far an intimate relation may be noted between the life-forms of the invertebrates. The differences between the secretions of limy matter by the amœba and by the sea-urchin; between the contractile action of the moneron in every part and the localisation of nerve-function in the medusa and the star-fish; between the vacuole of the amœba and the digestive canal of the sea-cucumber; are differences of degree and not of kind. They are one and all due to cell-modification arising out of advance from the like to the unlike, from the simple and general to the com-

plex and special, from the organless to the organised. They are thus types of the process of Evolution throughout the universe.

4. *Annelida and Arthropoda.*

The gradations between the infinite variety of life-forms are nowhere sharply marked, and this has led to the grouping of large numbers under one sub-kingdom, the feature common to all being the division of the body (which is developed from three layers of cells) into more or less well-defined rings or segments. It is also, like the body of vertebrates, 'bilaterally symmetrical,' *i.e.*, double and correspondent, so that if it were split lengthways the two halves would be seen to be almost exactly alike. The nervous system, which runs along the belly, consists of two fine cords, knotted at different points into ganglia or masses of nerve-cells, the first pair of ganglia being above the gullet, so that the cords which join the second pair form a collar round it. The important part which the mouth plays as the immediate channel between the animal and its surroundings accounts for the development of the higher organs of communication near it; the anterior or front segments most completely undergo concretion, and in this way the portion that carries the mouth, the chief nervous centre or brain, and the sensory organs, as eyes, ears, antennæ, is formed. Hence the position of the head or skull, as the protecting structure round the more specialised parts, is ruled by the position of

the mouth. The heart, which is tube-shaped, lies along the back, and the digestive canal lies between the heart and the nervous system. This arrangement distinguishes both earth-worms and wasps, leeches and crabs, centipedes and beetles, lobsters and ants—in fine, all but the very lowest classes. But the advance in complexity of structure—in other words, in division of labour—is especially shown in the more elaborate arrangements for the conveyance of nutrition throughout the body as compared with those arrangements in the lower sub-kingdoms. The oxygen and food are circulated by a highly organised fluid called blood, which carries them to every part, and likewise removes the waste and effete matter of the body. The immediate motor power by which the blood is driven is the heart, and its aëration—in other words, the supply of oxygen and the removal of carbonic acid—is effected by the respiratory organs. The lower animals breathe through pores or sacs in their sides; only the backboned animals breathe through the nostrils.

The animals ranging from worms to insects are divided into the *Annelida*, or footless, comprising worms and leeches; and the *Arthropoda*, or footed, comprising crabs and other crustacea, spiders, scorpions, centipedes, and all insects.

The lowest members of the Annelida, although the higher animals are more or less descended from them, are *Vermes*, or worms. They vary from the flat or ribbon-like, and thread-like forms—of which a vast number live as parasites outside or inside the

bodies of nearly all animals, passing, in some cases, from one animal to another—to the ringed forms, of which earth-worms, marine worms and leeches are the leading representatives. This is perhaps a suitable place to make reference to the isolated group named *Rotifers*, so called because of the ceaseless wheel-like (Lat. *rota*, a wheel) movements of the cilia round the mouth. These degenerate specks, some of which 'can sail through the prick of a needle's point,' although others are visible to the naked eye, are highly organized. They have a nerve ganglion which sends out threads to the ruby eye or eyes and antennæ; they have jaws and teeth, often a hard skeleton; the females have one and sometimes two stomachs, but the poor male has none. They can remain for a considerable time in a state of suspended animation.

The Arthropoda include the worm-like *Peripatus*; the *Crustacea* (lobsters, crabs, shrimps, etc.); *Myriapoda* (centipedes, millepedes); *Insecta*; *Arachnida* (spiders, scorpions, mites, etc.). *Peripatus* is an animal of great importance and antiquity, because it is believed to be nearly related to the ancestor of all air-breathing Arthropoda, *i.e.*, of all insects, spiders, and myriapods. It probably represents almost the earliest stage in the development of the wind-pipe-like tubes through which insects breathe.

The typical form—head; thorax or chest; and abdomen or belly—of the numerous varieties of the widely diffused *Crustacea*, or hard-shelled class, whose three-lobed ancestors, the trilobites, flourished in the seas of the Cambrian and later periods, is the same,

with infinite modifications in detail, as that of the Insecta and Arachnida. But in *Insects* these three divisions are sharply marked, the chest to which the legs and wings are attached, and the belly, being sometimes joined by a mere thread, whence the name given to that class, *Insecta*, 'cut into.' Their wings have been developed from organs which were adapted for breathing in the air as the necessity arose, and they ultimately became organs of flight when the creature left the water for the land. Here, as in aught else, the process was gradual, only such as were able to exist for a time out of the water winning in the struggle for life.

The larger number of animals pass through well-marked series of changes, but these take place within the egg, the food-store of which suffices for their development. Through lack of this supply most insects quit the egg in an immature condition, passing through the metamorphoses of grub, chrysalis, and imago. Like the rotifers, they rebuke the vulgar notion that wonder is to be proportioned by the size of the thing which arouses it. For the infinitely small is as fully charged with mystery as the infinitely great; the movements of forces and energies in both cell and crystal are more complex than the motions of the giant bodies of the heavens; the ultimate analysis of the atom is more elusive than that of the mass which it makes up.

In the beauty and delicacy of insect structure—notably in the wings, more perfect for flight than those of birds; in the infinite division of organs; the

spider, with its six hundred teats, spinning its web of as many strands; the dragon-fly, with its twelve thousand eyes, each with its own lens, cone, and rod; the caterpillar, with its fifteen hundred air-tubes—we learn that magnitude is not necessary to complexity. In the high nervous organisation of insects, and the variety of functions, many of these quasi-human, which they discharge; in the dexterity of their actions, and the manifest adaptation of means to ends; in the social order of certain species, notably the ant commonwealth, with its division of labour, its slave and fighting population, its farmers and miners, its nurseries for pets and weaklings, its burial customs, its political and industrial order, which has not, like ours, to readjust itself by peaceful or bloody revolutions to changing conditions—we have striking evidence of the interrelation of all living things and of the unreality of the distinctions which man has set up between instinct and reason; in fine, evidence of fundamental correspondence between the nervous systems of the lowest and the highest. Complexity, not size; mental, not physical power, mark advance in the organism; and it is in the specialisation of the nervous system, and in the proportion of its controlling centre, the brain, to the rest of the structure, that the mechanical explanation of intelligence lies. Darwin remarks that the brain of an ant, which is proportionately larger than that of any other insect, although itself not so large as the quarter of a small pin's head, is one of the most marvellous atoms of matter in the world, perhaps more so than the brain of a man.

There is much force in the argument that the long period of infancy, with its consequent dependence on parental love and care, through which man, and in lesser degree the highest apes and other animals, pass, has tended to develop the feeling of sympathy and of its expression in service of the helpless by which the family is knit together, and out of which has grown the social instinct which forms tribes and nations. Nor does the argument stop here. The longer the baby stage, the more intelligent is the animal; for where there is a complex nervous system its specialisation goes on after birth: whereas in the case of an animal with low capacities all the nervous connections are formed before birth, so that it begins life in lusty independence, fully equipped for work, and therefore with no tie to bind it to its parents, while its isolated life is fatal to mental development.

Now the ant, with other communal insects, as bees and wasps, has to pass through a relatively long grubhood, and in this we may have the explanation of its high social organisation, which has had measureless time for its development, since the remains of Hymenoptera are found as far back as the Jurassic age. And if the argument has any force in the case of man, the evolutionist is bound to apply it to the ant, with the important difference that the limits of the ant's development were reached long ago, the capacity to change varying inversely with the persistence of inherited qualities.

5. *Mollusca.*

This sub-kingdom, the importance of whose fossil remains has been indicated, includes a wide range of organisms, any common definition of which is difficult.

In the larger number of molluscs symmetry of form is more the exception than the rule. Some Mollusca have neither heads nor hearts, or at least quite imperfect ones; others have heads and chambered hearts; some grow together in colonies, others live an independent life; but all are alike soft-bodied, lacking segmented or jointed structure. Some, as the sea and land slugs, are naked, although furnished with a delicate shell when young; others have a leathery or gristly covering; the rest, the shell-fish proper, are protected by single or double valves, which in their spiral forms and fadeless colouring sometimes surpass the loveliest flowers, or which, as in the pearl oyster, yield the lustrous substance which, according to ancient fable, is formed of rain-drops falling into the open valve, where some mysterious agency transmuted them. The power of secreting matter from the surrounding water for the construction of their shells is one of the most persistent characteristics of the Mollusca, the shells (which are not cast periodically, as with the crustacea) being formed along the surface of the thick flexible skin called the 'mantle,' the crumpled line of which determines their shape. They range in size from the enormous Tridacna of tropical

seas, which sometimes weighs five hundred pounds, to the minute species of our coasts, thousands of which scarcely exceed an ounce in weight. One species, the *Clio borealis*, about an inch long, which is so abundant as to colour the surface of the Arctic seas for leagues, has no less than 360,000 suckers for capture of its prey attached to the wing-like organs which spring from its head.

The lowest molluscs are the plant-like, fixed *Sea-mats* and *Sea-mosses*; the highest are represented by the Briareus-like *Cuttle-fish*, from the common species of our seas to the octopus, with its rudimentary internal skeleton and its chameleon-like power to change its colour; and by the pearly *Nautilus*, the sole survivor of an ancient family that swarmed in the waters of the Jurassic and Cretaceous periods. Between these range the more familiar shell-fish, notably the oyster, which, in common with all bivalves, is headless; and the periwinkle, whose land congener is the air-breathing snail.

6. *Vertebrata.*

We now reach the last and highest of the divisions of animal life, the sub-kingdom of the *back-boned*, which includes man.

Professor Cope says that 'the simplest expressions which shall cover all organs are the solid segment, the hollow sac and tube.' The back-boned animals witness to this; they have fundamentally the same organs and parts as earthworms, passing through the same grades of structure. But while all invertebrates, except

the lowest, consist of a single tube or cavity containing the nervous and vascular (or circulatory) systems in common, and have an *outside* skeleton, which is simply a hardening of the skin, vertebrates consist of two tubes or cavities, the smaller of which encloses the central parts of the nervous system, or the brain and spinal cord, and the other the vascular system, or the organs of digestion and circulation, and have an *inside* skeleton. The most important part of this is the spine or back bone, which separates the tubes, and is made up of a number of jointed bones or vertebræ, united by remains of the cartilaginous notochord, which gives flexible action to the whole column. The advantage of this combined strength and ease of movement is seen in fishes as they dart through the water, in the gliding of the snake, the leap of the antelope, and the spring of the lion; while, as compared with animals which are either naked, or covered by a rigid horny skeleton, cumbersome as the armour of our ancestors, vertebrates have an enormous superiority in their internal framework of living bone, which adapts itself to, as well as nourishes and protects, the softer parts. Vertebrates, like the Annelida and Arthropoda, are bilaterally symmetrical, and are composed of segments placed one behind the other; but the lines of junction have become hidden by overlying muscles or effaced by structural modification—as, *e.g.*, in the formation of the skull, which is composed of nine or more coalesced segments. The threefold division of the body into head, chest, and belly, characteristic of crustacea and insects, is, however, more obvious.

The limbs never exceed four in number, and are in pairs, whether as fins of fish (not reckoning the unpaired fins as limbs), wings and legs of birds and bats, fore and hind legs of quadrupeds, or arms and legs of man ; all being modifications of one type, as in the prolonged bones of the bat's wing, which correspond to our fingers.

Such, in crude outline, are the principal features of the highest animals, but no general description can cover the infinite variety of vertebral forms. The sturgeon and the shark have a gristly spine ; the frog has no ribs ; the tortoise is encased in a shield composed of the hardened skin of its back and belly ; and even in the marked division of vertebrates into cold-blooded, embracing fish and reptiles, and warm-blooded, embracing birds and mammals, exceptions occur in warm-blooded fish, as the tunny and the bonito. But no differences in detail can obscure the fact that vertebrates are all modifications of a common type, the variations in structure being due to the differences of function determined by unlike modes of life. Moreover, details obscure relations ; and since it is with the relation of all life-forms that we are chiefly concerned, we may pass to further evidence of connection between the highest invertebrate and the lowest animal of vertebrate character. This is furnished by the marine worm *Balanoglossus*, because it is shown to possess gill-slits like sea-squirts and lancelets, and to develop in early life a short notochord. Of perhaps greater interest to the evolutionist are the transparent bag-shaped *Sea-squirts*, or *Ascidians*, which

were formerly classed by themselves under Tunicata (Lat. *tunica*, a cloak). Most of the species are immobile, attaching themselves to rocks, shells, and other objects, sometimes growing separately, and sometimes in colonies on a common stem. Of the two openings in their gristly covering, which is largely made up of cellulose, a characteristic element in plants, one is the mouth and the other the vent. The heart, a tube-shaped organ, is placed at the lower end of the body-cavity, which fills the space around the intestine. The nervous system, consisting of a single ganglion, lies between the mouth and vent. The position of this ganglion gives a valuable clue to the connection between the ascidians and the vertebrates, but still more important evidence as to this is supplied in the early stages of the ascidian's development. In certain species the egg gives rise to a larva resembling the tadpole of a frog, both outwardly and inwardly—a resemblance 'reaching absolute identity when we examine the way in which the various organs arise from the primitive egg-cell,' the only important difference being that the ascidian has but one eye. In connection with this Mr. W. B. Spencer's important discovery of a small eye beneath the skin on the top of the head of the Hatteria lizard in New Zealand, the representative of reptiles whose fossils occur in the Trias, may be noted. The larvæ of the ascidian and of the frog alike possess four structures which are common to every back-boned animal at some stage of its development, and the possession of which is explicable only on the theory of the descent of sea-squirts

and vertebrates from a common ancestor. These four structures are—(1) the throat with its gill-slits; (2) the primitive back-bone—a gristly rod called the notochord developed from the alimentary canal, and which is found in no invertebrates except the ascidi ans; (3) the brain and spinal cord; and (4) the eye, which is *inside* the brain.

Similar as are the larvæ of the tadpole and the sea-squirt, they diverge at later stages. While the one advances from the fish-like form to the amphibian, exchanging gills and tail for lungs and limbs, and, in fine, epitomising in its development the series of forms through which its ancestors passed, the other fixes itself by suckers to stone or plant. Tail, notochord, nerve-cord, and eye disappear, the brain remains small, the throat enlarges, the gill-slits increase in number, the skin becomes hard and leathery, and the eyeless, footless thing sinks well-nigh to the plant level, its vegetating mode of nutrition sealing its degeneration.

Another interesting link between the invertebrates and vertebrates is supplied by the *lancelet* (so called from its lance-like shape), or *Amphioxus* (Gr. *amphi*, both; and *oxus*, sharp; both ends being nearly alike). The mouth of this headless, one-eyed, semi-transparent animal has cilia for driving in the food-carrying water, and opens through the breathing slits into a wide gullet, in which the water, after giving up its oxygen to the colourless blood, enters and is expelled at the vent. There being no muscular heart, the blood is circulated by contractions of the vessels.

Now this boneless creature is classed among back-boned animals because it has the primitive gristly notochord from which the spine is developed in all true vertebrates. Above this rod lies the nervous system, composed of a single chord, which bulges slightly as a primitive brain near the mouth. The short notochord and single nerve-ganglion of the ascidian correspond, as far as they go, to like organs in the lancelet; and if they were lengthened, so as to run along the whole of the back of the ascidian, the positions in the two animals would be found to agree exactly. This certainly points to their common descent.

Fishes, as the least specialised vertebrates, although by no means so stupid as is commonly thought, are placed in the lowest class, many species, as sharks, rays, and sturgeons, representing in their gristly backbones, uneven tails, and spiny or plated skins, the armoured ganoids which mark the gradations between cartilage and bone in structure.

Just as we had to retrace our steps in search of a link between vertebrates and invertebrates, so we must again go back a step or two to find the intermediate forms between aquatics and amphibians. These forms, the evolution of which is probably due to their occasional exposure to the atmosphere, developing in them different organs of breathing, are represented by certain fishes called *Dipnoi*, or 'double-breathers,' because, while they have gills for taking up the oxygen from the water, they can also breathe on land by means of the air-bladder or sound, which thus discharges the functions of a lung. Such are the *mud-fish*

of the Amazons, and the *jeevine* of Australia, both of which show tendency towards modification of the paired fins into limbs, those of the mud-fish being thong-like, and those of the jeevine being jointed, for locomotion on land. Other fish, as eels and the climbing perch of India, can also leave the water, their breathing being effected by modification of the gills.

Here, then, we find another intermediate step between land-dwellers and water-dwellers, the most perfect and familiar example of which is supplied by the common frog's life-history. The gill-breathing, limbless, tailed, plant-eating, aquatic tadpole develops into the lung-breathing, four-legged, web-footed, tailless, animal-eating, amphibian frog, unable, save when torpid, to live in water without coming to the surface for air. Some amphibians possess both lungs and gills throughout life, but all the higher vertebrates, whether they live in water or not, breathe through lungs, which arise, like the air-bladder of fishes, as sac-like outgrowths of the primitive gullet.

Reptiles, which include forms as diverse as the nimble lizard, the sluggish crocodile, and the limbless snakes, are for the most part the relatively insignificant descendants of the monsters of the land, air, and water, that flourished in the Age of Reptiles amidst the dense vegetation of a swampy world, until conditions fatal to them, and favourable to the development of more plastic life-forms, supervened.

Birds, at the head of which our best authorities place the crow family, possess a number of special characters, chiefly connected with the power of flight,

from the path of which Roman augurs drew their omens of good or evil, as do the Papuans of to-day. Their exact sequence in the development of vertebrates is unknown, but their descent from land reptiles is certain. But, although structural likenesses between birds and reptiles survive to attest this former close relation, manifold causes, working through long periods, have brought about marked differences of external and internal structure. Notable among these is the modification of the three-chambered heart of nearly all reptiles into the four-chambered heart of birds and mammals, by which the fresh and used-up blood are kept separate, and the higher temperature of the body is maintained. The scales of the one, and the feathers or downy covering of the other, are alike modifications of the outer skin; for although the intermediate stages between the plumage of birds and the horny plates of reptiles are missing in fossil remains, it is certain that these and kindred structures, as hairs, claws, nails, teeth, and hoofs, are all outgrowths of the skin. It has been shown already that the nervous system and sense-organs are also formed from the skin.

The lowest members of the diversified group of *Mammals* or milk-givers resemble birds in being toothless, and in having a common sac into which the intestines and other organs open, for which reason they are called *Monotremes*, or one-vented. These quasi-mammals are represented by the ornithorhynchus, or duckbill, a beaver-like creature with a horny beak, the feet being furnished with both webs and

claws ; and by the echidna, or spiny ant-eater, which resembles a large hedgehog, being snouted and covered with prickles. Each is found in Australia, that land of primitive forms, and recent discoveries invest them with the greatest importance. For they both lay eggs like reptiles and birds, and the eggs further correspond with those of birds and reptiles in containing not only the protoplasm from which the embryo is formed, but also the food-yolk on which it is nourished until hatched, when it lives on the milk obtained from the mammary glands. Now an animal that unites in itself these reptilian and mammalian features is to be classed among the interesting anomalous and intermediate forms which Darwin has happily termed 'living fossils.'

The next stage in mammalian development is marked by the *Marsupials*, or *pouched milk-givers*, as kangaroos and opossums, the young of which are born in an imperfect condition, and nourished and kept in the mother's pouch till they can run alone. Their fossil remains evidence a wide range in Triassic times, and the Post-Pliocene beds of Australia yield bones of marsupials as large as elephants ; but their habitats are now limited to that island continent, and to lands similarly long isolated.

In all other mammals the young are born fully formed, being attached during the time of their development within the mother to a structure called the *placenta*, through which they are nourished by her, whence the general term placental mammals, of which the insect-feeders appear to be the primitive type.

Starting thus more or less fully equipped in the struggle for life, the chances in their favour were incomparably greater than those of animals which are precariously hatched or born in an imperfect state; hence, among other causes, the dominance of the placentals, and their development into the highest organisms yet reached.

They are usually divided into the following classes, which indicate structural characters common to the animals included under each, and not the exact relative place of the class in the sub-kingdom. No linear arrangement of classes, nor even of species, is possible, for the succession of forms is not as that of steps of a ladder, but as of a many-branched tree.

1. TOOTHLESS (*Edentata*)	Sloths; ant-eaters; armadillos. These show affinities linking them nearer to monotremes than to marsupials.
2. SIRENS (*Sirenia*) So called from their fancied resemblance to mermaids or sirens.	Dugongs and manatees, or sea-cows; fish-like in form, the fore limbs modified into paddles, the hind limbs absent; both these are plant-feeders.
3. WHALE-LIKE (*Cetacea*)	Whales; dolphins; porpoises; also adaptation of structure to aquatic life.
4. HOOFED (*Ungulata*)	Very numerous and valuable order. Divided into the *odd-toed*—as the horse, the tapir, and his near relation the rhinoceros; and the *even-toed*—as swine, and their near relation the hippopotamus; camel; deer; sheep; ox: all these are plant-feeders.
5. HYRAX, or ROCK-RABBIT (*Hyracoidea*)	Represented by a small animal, the 'coney' of the Bible. The shape of the teeth points to affinities with hoofed animals on the one hand and gnawing animals on the other.

Gibbon. Orang. Chimpanzee. Gorilla. Man.

SKELETONS OF MAN AND APES.

Reduced from diagrams of the natural size (except that of the gibbon, which was twice as large as nature).

(From Professor Huxley's *Man's Place in Nature.*)

6. TRUNKED (*Proboscidea*)	Represented only by the elephant, the longest lived and most acute of plant-feeders.
7. FLESH-FEEDERS (*Carnivora*)	Seals; bears; weasels; wolves and other members of the dog family; lions and other members of the cat family.
8. GNAWERS (*Rodentia*)	Hare; rat; beaver; squirrel. A very wide-spread class.
9. INSECT-FEEDERS (*Insectivora*)	Mole; hedgehog; shrew.
10. FINGER-WINGED (*Cheiroptera*)	Bat, highly organised, closely allied to insect-feeders.
11. PRIMATES	1. Lemurs. 2. Monkeys; baboons; man-like apes (gibbon, orang-outang, chimpanzee, gorilla), big-jawed, small-brained, stooping posture; MAN, big-brained, erect posture—divided into races according to shape of skull, colour of skin, nature of hair.

In the foregoing survey of past and present life-history no break in the continuity of life, or in its fundamental unity, is found. But, strive as we may not to overlay with detail, it is not easy to keep clear and constant before the mind the relationship between all life that is and that has been, as well as the identity of that life with, and its dependence upon, the not-living. Perhaps this interrelation may be made more apparent in the exposition of the theory of evolution which is now to follow the description of the things evolved.

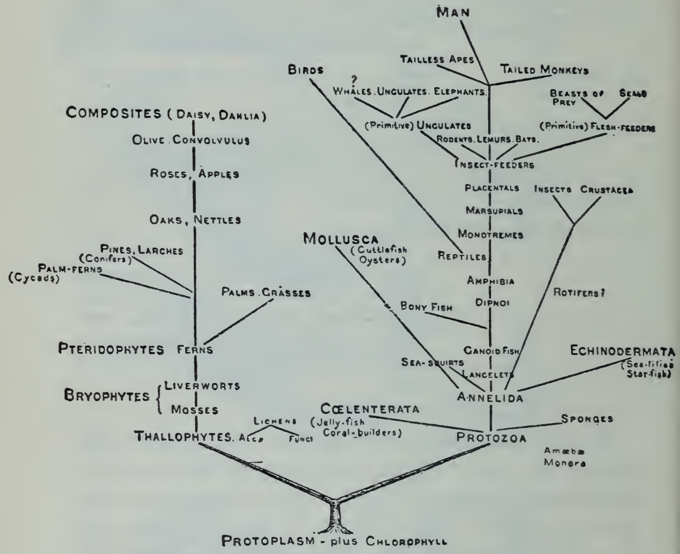


Diagram of Development.

The ascent of the higher life-forms from the lower is more lateral than the lines indicate, but the diagram is only a rough attempt to show the relative places of the leading groups.

PART II.—EXPLANATORY.

CHAPTER VI.

THE BECOMING AND GROWTH OF THE UNIVERSE.

In the first chapter a summary account was given of the materials which make up the universe. These were comprised under the terms Matter and Motion, as convenient names for an observed order of facts of whose ultimate nature we know nothing. As explained already, it is upon the twofold and opposite action of Motion that we base our assumption as to the nature of Matter—*i.e.*, as consisting of atoms of infinite minuteness.

That form of Motion which draws the atoms together into larger or smaller masses, and which resists their separation, we call Force; that form of Motion which drives the atoms apart, and resists their combination, we call Energy. Both Force and Energy are, like Matter, indestructible; in other words, the sum-total of each is a fixed quantity. Force inheres in, and cannot be taken from, each atom of weighable matter; but Energy passes from atom to atom, and from mass to mass, its vehicle being that un-

weighable ethereal medium which, it is assumed, fills the spaces between bodies and between the particles of bodies. In this diverse way each is ceaselessly acting, Force aggregating the particles round various centres, Energy separating them and passing into space, only fractions of it striking intervening bodies, as, *e.g.*, in the interception of the sun's radiant energy by the planets. And the certain result, however immeasurably distant, is that all the Energy of the universe will be dissipated, and that all the matter of the universe will become cold, solid, and inert under the aggregating and unopposed action of Force.

The problem we have now to consider is this:—Given Matter and Motion as the raw materials of the universe, is the interaction of Motion, under its two forms of combining Force and separating Energy, upon Matter, sufficient to account for the non-living and living contents of the universe?

If we speculate at all upon the subject, we cannot think of Matter and Motion as other than eternal, since 'out of nothing, nothing comes.' But as everything points to the finite duration of the universe as we know it—for what it now is it once was not, and its state is ever changing—we must make a start somewhere. 'All science starts with hypotheses' (see page 8), and we are therefore compelled to posit a state when the atoms, with their inherent forces and potential energies, stood apart from one another. Not evenly distributed, else Force would have drawn them together as a uniform spherical mass round a common centre of gravity, and Energy, awakened by the col-

lision of atom with atom, would have passed profitlessly in the form of heat to the ethereal medium; but varying in position and character, with special gravitation towards special centres. This theory of unstableness and unlikeness at the outset squares with the unequal distribution of Matter, with the movements of its masses in different directions and at different rates, and with the ceaseless redistribution of Matter and Motion. All changes of state are due to the rearrangements of atoms through the play of attracting forces and repelling energies, resulting in the evolution of the seeming like into the actual unlike, of the shapeless into the shapely, of the simple into the more and more complex, till the highest complexity is reached in the development of living matter. But if all that is, from fire-fused rock to the genius of man, was wrapped up in primordial matter, with its forces and energies, we can speak of simplicity only in a relative sense as contrasted with the infinite variety around us which has been evolved.

1. *Inorganic Evolution.*—Under this head we may apply the foregoing principles to the earliest stages of cosmical change, to the *Evolution of Stellar Systems.*

The existence of nebulous or cloud-like objects in space, which the telescope, aided by the analysis of the spectroscope, proves to be immense masses of glowing gas, goes far to justify the assumption of a yet more discrete state of the atoms which formed the material universe at the outset. But, although we are familiar with matter in an invisible state (see

page 7), we can form no conception of the extreme rarefaction of the primitive atoms. Upon this Helmholtz remarks that, 'if we calculate the density of the mass of our planetary system at the time when it was a nebulous sphere which reached to the path of the outermost planet, we should find that it would require several millions of cubic miles of such matter to weigh a single grain.' Given, however, the play of force and energy upon this diffused matter, the mechanics of the process which resulted in the visible universe are not difficult of explanation. The Force bound up in each atom, acting as *affinity*, combined the atoms as molecules; acting as *cohesion*, it united the molecules into masses; acting as *gravitation*, it drew the masses towards their several centres of gravity. One of these masses, by no means the largest, became the nucleus of our solar system, which may be taken as a type of all other masses whose evolution into stellar systems is as yet complete.

As the atoms rushed together, Energy, which had hitherto existed in a state of rest as passive separation, became active in *molar* and *molecular* form. As *molar* energy it imparted motion to each mass—a motion of rotation on its own axis; and a motion in an orbit, as in the proper motion of double stars, and of the planets round the sun. As *molecular* energy it imparted a rapid vibratory backwards and forwards motion to the molecules, which motion was forthwith converted into the radiant energy of heat and light, rendering the mass self-luminous. But from the moment of their conversion the dissipation of

both forms of energy ensued. The friction of the ethereal medium slowly retards the orbital motion of every mass, the *molar energy* thus lost passing into that medium, until finally the orbital motion will be stopped, and the force of gravitation, no longer resisted by energy, will draw the smaller masses to the larger, as vagrant meteors are being ceaselessly drawn to planets and sun. Moons will gravitate to their planets, planets to their suns, and so on, until the matter of the universe, with intermediate outbursts of energy, becomes cold, inert, and solid, and Force will have subdued all things unto itself. The *molecular energy* likewise passes, but more rapidly, into the ethereal medium, throbbing ceaselessly in all directions to the farthest marge of space, if any marge there be.

2. *Evolution of the Solar System.*—We may now apply the foregoing theory to the evolution of the system to which we belong, and to that portion of it which we call the earth. If the explanation of the origin of the sun and planets repeats somewhat of the foregoing, it will only bring home to us the uniformity of the process, and show that what is true of the whole holds good for every part, and for the parts of every part down to the unseen atoms of which all things consist.

Two striking pieces of evidence of the common origin of the sun and planets may be cited at the outset: (1) They are, speaking broadly, made of like materials; (2) they have like motions.

(1) The spectroscope has revealed to us the exist-

ence of substances in the glowing vapours of stellar atmospheres akin to those in the atmosphere of the sun; for example, the spectrum of Capella is almost identical with that of the sun. If such identity of stuff is proved to exist between him and other stars, we may look for still closer identities between him and his family of planets, moons, and erratic bodies. At least thirty-six of the elements of our earth are known to be present in the solar spectrum. The presence of oxygen is not yet proven, but no astronomer of repute believes that it is absent from the sun.

(2) The planets and, with rare exceptions, their satellites, revolve round him in the same direction; they also, so far as is known, rotate on their axes in the same direction, and very nearly coincide in the shape and planes of their orbits, which are almost in a plane with the sun's equator. Now, since the consequences would be the same were these motions, both on axis and in orbit, in the reverse direction, the inference is obvious that there was a uniform motion of rotation of the mass from which they were severally formed.

As with the primitive nebula from which that mass was detached, so with the mass itself; there were differences of density throughout. On no other theory is its segregation into a multitude of bodies explicable. As the rotation of the mass quickened with the indrawing of the particles towards the common centre of gravity, the energy of molar separation acted most powerfully in the region of the bulging equator, and, overcoming the force of cohesion along the line of

least resistance, detached certain portions one after another at irregular intervals from the central mass as it retreated within itself. These portions were the nuclei of the planetary groups, in which the like processes of contraction and rupture were repeated, the masses detached becoming moons, or, as in the case of Saturn, three rings of innumerable particles. The diffused and highly energised fugitive masses, as comets and other swarms of meteorites, are probably 'products of expulsion from suns, from giant planets, and from orbs like our earth when in the sun-like state.'

The origin of the planets and their moons being found in the mode described above, it is obvious that in their primitive state they were molten, and shone by their own light. All hot bodies part with their heat to cooler bodies; and when equilibrium of temperature is reached, all separative motions cease—no work can be done. The smaller the body, the sooner would its molecular energy be dissipated; in simpler words, the quicker it lost its heat. The present in a large degree interprets the past, and explains the several stages of the members of our system, according to their bulk. The sun, whose mass exceeds the combined mass of all the planets more than seven hundred times, is still slowly contracting, and therefore still radiating energy. For his heat is not kept up by combustion; despite his great bulk, he would, if made of solid coal, burn out in less than six thousand years. It is in a small degree increased by the meteorites which fall into him, and is chiefly main-

tained by the shrinkage of his mass, which causes a contraction of 220 feet yearly, or four miles a century in his diameter; so that he will be as dense as the earth in a few million years, and become a non-luminous star. The cloud-laden atmospheres of the larger planets, as Jupiter and Saturn, are torn by cyclones only second to those of the sun in their fury, and the molten centres feed volcanic outbursts to which those of Vesuvius and Krakatoa are mere squibs. But as for the smaller bodies, their turmoil is calmed and their light extinguished; the store of energy is exhausted; the forces of affinity and cohesion have gained the upper hand and drawn the particles together into the solid form. Thus it is with the airless moon, on whose scarred surface, pitted with extinct volcanoes, crossed by barren mountain ranges and covered with treeless plains, we may read the future of the giant planets and the sun himself. For the history of one is the history of all; each has passed, or is passing, from the indefinite nebulous state, through numberless modifications, to the definite and solid state, by decrease in volume and increase in density. What the earth is, the moon was; what the moon is, the earth will be.

3. *Evolution of the Earth.*—To this passage from the sun-like to the solid state the earth bears witness. Its flattened poles, its bulging equator, its spheroidal shape, are the effects of rotation on a fluid or viscous mass; while the geologically oldest parts of the crust are of a structure which is producible only by the fusion of particles under intense heat. As that crust,

thin and mobile at the outset, continued to cool and thicken, it evidenced more strikingly the play of forces and energies within, and of energies and, in lesser degree, of forces without. The cooling and shrinking of the internal mass, as the stored-up energy slipped away, caused tension of the crust, which, yielding to the force of gravitation, was drawn inwards, and crumpled into mountains and valleys, and into the deep depressions filled by the great oceans. Then the continuous action of the sun's radiant energy, operating through air and water upon the increasingly rigid crust, dissolved its superficial particles, and re-deposited them as stratified rocks, over the surface of the globe. And herein lies the major cause of our earth's present condition as a possible abode of life. For its native supply of energy—that of position derived from the momentum given it when thrown off from the parent mass—and its still unspent, but always lessening store of internal heat, would not suffice to arrest the wrapping of the globe in a winding-sheet of ice. It is the energy radiated from the sun which alone does that, setting up the separative motions, the ceaseless redistributions, which give rise to the grand climatal and vital phenomena of nature. But the full significance of the work done by the sunbeams that strike the earth's surface will appear when we treat of the relation of the living to the non-living.

CHAPTER VII.

THE ORIGIN OF LIFE.

It is agreed that there was an azoic or lifeless period in the history of the earth—therefore that life had a beginning; and it is with the evidence as to continuity or gap between the azoic and the zoic epochs that the present chapter is concerned.

The azoic stage is evidenced by the primordial temperature of the globe, which, taking the present temperature of the sun as a fair standard of comparison, is computed to have been fourteen thousand times hotter than boiling water. If under such highly energetic conditions chemical combinations of the vaporous particles were impossible, still more would this apply to vital combinations. But with the slow cooling consequent upon the continuous passage of the earth's molecular energy into space, the combining forces came into more and more active play, forming first the extremely simple and more stable compounds, as water; then the more complex and less stable, as salts; and so on in increasing complexity of material and unlikeness of structure. Obviously an enormous fall in the temperature took place before the superheated mass became cool enough to permit the formation of an outer crust. It was into

the depressions of this crust that the vapours which floated over it fell as they condensed, forming water, which at first was probably at the temperature of a dull red heat.

Thus far, in broad outline, the material foundation for the superstructure of life.

When, *where*, and *how* did life begin?

As to the *time*, we have no evidence whatever. Life is enormously older than any record of it. Even the higher forms were developed long before the periods in which we first find their remains.

As to the *place*, probably in polar regions, as Buffon suggested in his 'Époques de la Nature.'

As the globe cooled, those regions would be the earliest to reach a temperature under which life is possible. The Comte de Saporta remarks that the richest fossil-yielding rocks are found in northern latitudes of 50° to 60° and beyond, and show that far back as Silurian times the north pole was warm enough to maintain life of a tropical character, and that it was the centre of origin of successive forms down to the Tertiary epoch; the Miocene flora, which has now to be sought 40° further south, being profusely represented. In Carboniferous times a warm, moist, equable climate prevailed over the whole globe, due, as De Saporta argues, to arrest of radiation by a highly vaporous atmosphere, and also, perhaps, to the greater diffuseness of the sun's light by reason of his larger volume. Thiselton Dyer says that all the great assemblages of plants seem to admit of being traced back at some time in their history to

the northern hemisphere with its preponderating land-surface.

As to the *mode*, let us approach the problem by treating of what is common to both the lifeless and the living. Now, in brief, there are no elements in the one which do not occur in the other. The highest plant and animal, and the lowest living germ, are alike made of materials derived, directly or indirectly, from earth and air and water. These materials are oxygen, carbon, hydrogen, nitrogen, with a little sulphur and phosphorus, and still fainter traces of other elements, some twelve in all. Of the several entering into this subtile combination, the most prominent part is probably to be assigned to carbon. Its affinity for itself, and its faculty of uniting in manifold relations both of number and weight, cause its compounds to be more numerous and important than those of all the other elements taken together. Combining with the foregoing elements, it gives rise to protoplasm, and as the cell is an organisation formed from protoplasm, and marks the first stage in visible structure, the question as to the mode of origin of life narrows itself to the origin of protoplasm. Given the matter which composes it, and the play of forces and energies of which that matter is the vehicle, wherein lies the difference which gives as one result non-living substance, and as another result living substance? The answer obviously is that, *the ingredients being the same, the difference must lie in the mixing.*

We are already familiar in the inorganic world with the existence of the same element in more than

one form, but with different characteristics—*e.g.*, of carbon, as diamond, graphite, and charcoal; the difference being doubtless due to molecular arrangement. The chemist has manufactured organic compounds, as starch, urea, and alcohol, the production of which was once thought impossible, and has so imitated the structure and movements of protoplasm as 'to deceive the very elect.' And is not Nature—the alchemist, who keeps her secret well—ceaselessly transmuting the inorganic into the organic within the laboratory of the plant under the agency of chlorophyll?

In truth, the ultimate cause which, bringing certain lifeless bodies together, gives living matter as the result, is a profound mystery. 'The transition between the organic and inorganic energies may be possibly found in the electric group. Its influence on life, its production of contractions in protoplasm, and its resemblance to nerve-force, are well known. It also compels chemical unions otherwise impracticable.' More and more does modern research show the connection of all vital phenomena with electrical changes. But, although the living thing affects us much more nearly than lifeless stones and rain, it hides no profounder mystery than they. The origin of life is not a more stupendous problem to solve than the origin of water. Both protoplasm and water have properties that do not belong to the individual atoms which compose them, and the greater complexity of the living structure does not constitute a difference in kind, but only in degree.

Speaking relatively—for, as has been shown, nothing is absolutely motionless—the crystal is stable, irresponsive: the cell is plastic, unstable, responsive, adapting itself to the slightest variation, and thus undergoes ceaseless modification by interaction with its ever-changing environment. Life involves delicacy of construction; hence the transient nature of the organic in contrast to the abiding nature of the inorganic. And, strange as it may seem, separation is life; integration is death. For life is due to the sun's radiant energy, which, setting up separative movements, enables the plant to convert, through its mysterious alchemy, the lifeless into the living, thus forming energetic compounds, which are used partly by the thrifty plant for its own vital needs, and largely by the spendthrift animal for its nutrition. Ultimately the energy thus derived from the sun, directly by the plant and indirectly by the animal, passes into space, and 'the dust returns to the earth as it was.' For life is only a local and temporary arrest of the universal movement towards equilibrium.

Turning to mental phenomena, from its lowest manifestations in the simplest reflex action of the amœba or the sundew when touched, to its highest manifestations in consciousness or self-knowledge, we find the connection between it and the bodily movements a greater *crux* than the connection between the inorganic and the organic. We know that all the thoughts we think, and all the emotions we feel, involve a physical process; that is to say, they are accompanied by certain chemical changes or

molecular vibrations in nerve-tissue, involving waste or large expenditure of energy, which is repaired by food. We know that the healthy working of the brain depends upon nourishment, upon abstinence from excess, upon freedom from injury. Starve, or stun, or stupefy a man, let palsy or paralysis afflict him, and the complex machinery is thrown out of gear. And we know that the larger the proportion of brain to body, and especially the more numerous and intricate the furrows and creases in the grey matter of the brain, the higher in the life-scale are the mental powers.

But the gulf between consciousness and the movements of the molecules of nerve-matter, measurable as these are, is impassable; we can follow the steps of the mechanical processes of nerve-changes till we reach the threshold which limits the known, and beyond that barrier we cannot go. We can neither affirm nor deny; we can only confess ignorance.

CHAPTER VIII.

THE ORIGIN OF LIFE-FORMS.

MOISTURE as well as heat is essential to life ; therefore life had its beginnings in the universal solvent, water, but whether as plant or animal is a difficult question to answer. The fossil-yielding rocks tell us nothing about it, and the lowest and simplest organisms have so much in common that any attempt to gather evidence from them on the matter must fail.

It has been shown that the plant alone has the power to convert the elements of lifeless matter into the living solid state, thereby storing up energy for its own use in growth and germination, and for the use directly or indirectly of the animal. This the plant is enabled to do solely in virtue of the green colouring matter called chlorophyll, which absorbs certain sun-rays, and sets up chemical action by which carbon is separated from oxygen in carbonic acid gas, and hydrogen from oxygen in water, forming hydrocarbons in which energy is stored up. Now, if the animal is entirely dependent upon the plant for this energy, it would seem that plants were developed first.

Authorities, however, differ on this question of the priority of the plant, but it has no serious importance

in view of their agreement as to the common evolution of living things, and we may therefore pass to inquire into the causes which have developed both plant and animal from specks of relatively formless protoplasm.

The cell is the structural starting-point of all life. The nucleus which it encloses is the result of the first visible approach of protoplasm to unlikenes of parts, and is the chief centre of activity. The single cell of which the Protozoa are composed does everything appertaining to life: it feels, moves, feeds, and multiplies. In the Metozoa these functions are divided among the cells, each of which is independent, but nevertheless adapts itself for the work it has to do, acting in common with its fellow-cells. Division of labour causes difference of structure—stem, root, sap, leaf, and seed in the plant; bone, muscle, nerve-tissue, blood, and egg in the animal: all are communities of cells of astounding minuteness variously modified. The organism is the sum of life of all the cell-units.

The one-celled forms increase by division. Growth is the balance of repair over waste; and when through assimilation of food into its substance the cell reaches a certain size, the force of cohesion is overcome by the release of the energy derived from food, and the cell divides equally at the kernel or nucleus. The slimy protoplasm distributes itself around each nucleus as the two part company, to grow and divide again in like manner *ad infinitum*.

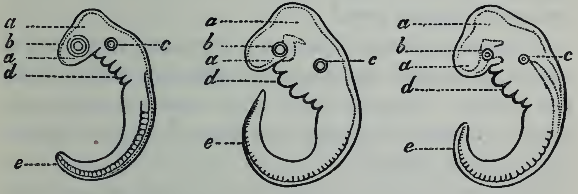
In many Protozoa a small portion of the parent is detached—a process known as generation by budding; but this and other modes of whole or partial fission

are classed together as reproduction by multiplication.

The next stage in structure is when the cells in dividing remain, to their common advantage, grouped together, as in all animals above the Protozoa.

The cells divide in definite order into two, then into four, eight, sixteen, and so on, clustering together in a morula, or mulberry-like mass, in which a cavity filled with fluid is formed, the cells being parted and driven to the surface. Mutual pressure, as they continue to subdivide, causes them to flatten and range themselves side by side in a single layer, forming what is called a blastosphere (Gr. *blastos*, a bud). By a process which is somewhat obscure (for we are dealing with the movements of very minute bodies), but which corresponds to the conversion of a small india-rubber ball, having a pinhole in it, into a two-walled cup by pushing it in with the finger, the single-layered sphere becomes changed into a double-layered hood or horseshoe-like structure, called a gastrula (Gr. dim. of *gaster*, stomach). The simpler stationary animals, as sponges and polyps, do not advance beyond this stage, but in all animals above them, in which bilateral structure, probably through free movement in a given direction, is developed, a third layer, larger and more complex, arises. The other two layers apparently take an equal share in its formation, and from its subdivision the greater number of organs of the body, be it of a worm or a man, are developed. Passing over much technical detail, it must suffice to say that the upper layer gives

rise to the skin, the nervous system, and organs of sense; the lower layer to the intestinal canal and appendages; and the middle layer to the general skeleton, the heart, and other important organs. Thus does the future animal emerge from the gastrula stage, and pass into the embryo stage, up to an advanced period in which the embryos of vertebrates, whether



Fish. Dog. Man.

CORRESPONDING STAGES IN THE DEVELOPMENT OF FISH, DOG, AND MAN.

a, brain; *b*, eye; *c*, ear; *d*, gills; *e*, tail.

fish, tortoise, dog, ape, or man, cannot be distinguished from one another, so close are the likenesses both in appearance and structure.

All plants and animals above the lowest are reproduced by the agency of special cells, the impregnation of the nucleus of the germ or egg-cell of the female by the nucleus of the sperm-cell of the male being necessary to set up the series of changes which result in the future animal. There are numerous variations in the organs of reproduction, but whatever unlikenesses exist in detail do not affect this general statement; alga and oak, sponge and man, are alike developed

from germs variously called spores, sacs, seeds, and eggs. The structure of the fertilised egg of the parent determines the structure of the offspring, which to some extent reproduces the series of forms through which its ancestors passed as it progresses to its adult state. In other words, the individual, as it develops from the egg-cell, epitomises the history of the ancestral forms of its species; as has been aptly said, it 'climbs up its own genealogical tree.'

The transmission of parental form and structure, as well as of mental character, to offspring, being clear, the question suggests itself, How have variations, resulting in millions of past and present species of plants and animals, arisen?

Professor Huxley says that 'the great need of the doctrine of evolution is a theory of variation.' That is so, but when we consider the mobility and minute complexity of structure of living things invisible to the naked eye, and their response to every shiver of energy from without, we have the conditions for the production of unstableness which will result in unlikeness of parts. Given a body which, although a minute speck, contains billions of molecules performing complicated movements of immense rapidity, and sensitive in an inconceivable degree to the play of vibrations impinging upon them at the rate of hundreds of trillions per second, would not the marvel be if these quivering particles of the structure, shaken by energies within, and by still more potent energies without, did not undergo continuous redistribution.

The position may be thus stated:—The organism

has—(1) Infinite complexity of structure; (2) inherited tendencies; (3) mobility and continuous motion, therefore capacity to vary. (4) Variations are induced by the surroundings on which, as vehicles of energy, life depends; (5) when the surroundings change, the organism adapts itself or not to the change; (6) such as fail to adapt themselves perish; (7) such as adapt themselves vary in greater or lesser degree; (8) these variations, being transmitted, are stages in the development of different life-forms. To put the matter briefly, likenesses are inherited, variations are acquired.

This brings us to the theory linked with Darwin's name, which explains by what operation of natural causes the highest plants and animals have descended by true generation and slow modification from less complex life-forms, and these in ever-lessening degrees of complexity and unlikeness, until the common starting-point from the lowest or one-celled organism is reached.

Following Lyell's method of explaining the past by agencies still in operation, and adapting hints from Malthus and other writers in the clearing up of questions suggested by observations extending over many years, Darwin propounded a theory which accounts in large degree for the origin of species. This theory is explained in the next chapter.

CHAPTER IX.

THE ORIGIN OF SPECIES.

It should be noted at the outset that 'species' is a convenient term to denote groups of individuals having certain characters in common, but that no one definition of 'species' has satisfied all naturalists. The term 'variety' is almost equally difficult to define; but, practically, when a naturalist can unite by means of close intermediate links any two forms, he treats the one as a 'variety' of the other, ranking the most common, but sometimes the one first described, as the 'species,' and the other as the 'variety.'

1. *No two individuals of the same species are exactly alike; each tends to vary.* Of this obvious fact every species, with their several varieties, from man downwards supplies abundant illustration. Of the hundreds of thousands of faces that we meet in the course of a year in any large city, each has some feature to mark it from every other; the practised eye of the shepherd recognizes each sheep in his flock, of the Laplander each reindeer among the crowded herd, and of the gardener each hyacinth among a thousand bulbs. Children of the same parents vary in size, feat-

ure, complexion, character, and constitution, sometimes very obviously, but sometimes too obscurely for cursory detection; and this law of general resemblance, with more or less variation in detail, applies to all animals and plants. The tendency to vary, which in our ignorance of its ultimate cause we say 'inheres' in the organism, and of which what are called 'sports'—as when a bud or shoot assumes a new and different character from the rest of the plant—furnish the best illustration, is fostered by the change of condition in which the animal or plant may be placed, as shown in its more marked tendency to vary in a domesticated than in a wild state. For example, when the common ringed snake, which in its natural state is oviparous, is confined in a cage in which no sand is strewn, it becomes viviparous.

2. *Variations are transmitted, and therefore tend to become permanent.* In other words, what is peculiar to the parent plant or animal reappears in the offspring. This is known as 'descent with modification,' the import of which will be shown later on.

3. *Man takes advantage of these transmitted unlikenesses to produce new varieties of plants and animals.* He selects certain individuals possessing variations which he wants to preserve, and allows only them to breed together, by which means in the course of time he produces varieties differing greatly from the parent form with which he started. The stock example of this is the pigeon. All our domestic pigeons, exceeding in number a hundred well-marked races, are descended from the ordinary blue

rock pigeon of the European coasts. The same method has given us different races of dogs, sheep, horses, and other domestic animals. The fleetest horses are chosen to breed together; in the development of the cart-horse, strength, not speed, is the quality selected; while in the marked unlikeness between dogs we see the result of artificial selection in producing such varieties as the bloodhound, the terrier, and the spaniel. What varieties in flowers, vegetables, and fruits, the like method has induced, is too well known to need detailed reference here. When we see how successfully this choice of slight variations has brought about plants and animals best adapted to the service of man, we may desire the time when man shall so realise his duty to the race that the multiplication of the rickety, both physically and morally, will cease, and only men and women of the highest type reproduce their kind.

Now the important work which Darwin did was to show that what man does on a small scale within a limited range of time, nature does on a large scale during countless epochs; with the further difference that the action of nature is not purposive, as is the action of man, but involved in the necessities of things. We may quote what Darwin says on this matter:—

As man can produce, and certainly has produced, a great result by his methodical and unconscious means of selection, what may not natural selection effect? Man can act only on external and visible characters: Nature, if I may be allowed to personify the natural preservation or survival of the fittest, cares nothing for appearances, except in so far as they are useful to any being. She can act on every internal organ, on every

shade of constitutional difference, on the whole machinery of life. Man selects only for his own good : Nature only for that of the being which she tends. Every selected character is fully exercised by her, as is implied by the fact of their selection. Man keeps the natives of many climates in the same country ; he seldom exercises each selected character in some peculiar and fitting manner ; he feeds a long and a short-beaked pigeon on the same food ; he does not exercise a long-backed or long-legged quadruped in any peculiar manner ; he exposes sheep with long and short wool to the same climate. He does not allow the most vigorous males to struggle for the females. He does not rigidly destroy all inferior animals, but protects, during each varying season, as far as lies in his power, all his productions. He often begins his selection by some half-monstrous form, or at least by some modification prominent enough to catch the eye or to be plainly useful to him. Under Nature the slightest differences of structure or constitution may well turn the nicely balanced scale in the struggle for life, and so be preserved. How fleeting are the wishes and efforts of man ! how short his time ! and, consequently, how poor will be his results, compared with those accumulated by Nature during whole geological periods ! Can we wonder, then, that Nature's productions should be far 'truer' in character than man's productions ; that they should be infinitely better adapted to the most complex conditions of life, and should plainly bear the stamp of far higher workmanship ?'

4. *More organisms are born than survive.* To quote Darwin once more, 'there is no exception to the rule that every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow-breeding man has doubled in twenty-five years, and at this rate in less than a thousand years there would literally not be standing room for his progeny.' If all the offspring of the elephant, the

slowest breeder known, survived, there would be in seven hundred and fifty years nearly nineteen million elephants alive, descended from the first pair. If the eight or nine million eggs which the roe of a cod is said to contain developed into adult cod-fishes, the sea would quickly become a solid mass of them. So prolific is its progeny after progeny, that the common house-fly is computed to produce twenty-one millions in a season; while so enormous is the laying power of the aphis, or plant-louse, that the tenth brood of one parent, without adding the products of all the generations which precede the tenth, would contain more ponderable matter than all the population of China, estimating this at five hundred millions!

It is the same with plants. If an annual plant produced only two seeds yearly, and all the seedlings survived and reproduced in like number, one million plants would be produced in twenty years from the single ancestor. Should the increase be at the rate of fifty seeds yearly, the result, if unchecked, would be to cover the whole globe in nine years, leaving no room for other plants. The lower organisms multiply with astonishing rapidity, some minute fungi increasing a billionfold in a few hours, while the protococcus, or red snow, multiplies so fast as to tinge many acres of snow with its crimson in a night. But we need not give further examples of this fecundity whereby nature, 'so careless of the single life,' secures the race against extinction.

5. *The result is obvious: a ceaseless struggle for food and place.* In that struggle the race is to the swift,

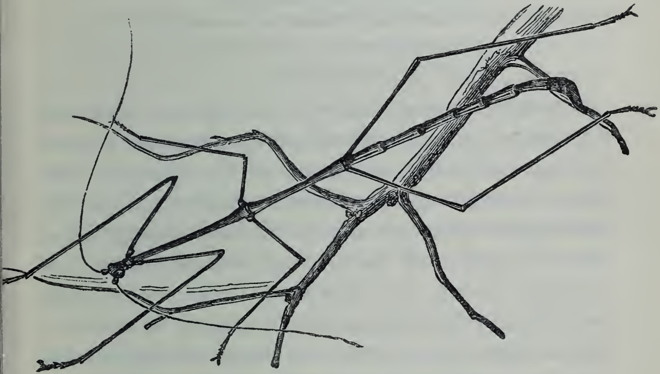
and the battle to the strong; the weaker, be it in brain or body, going to the wall, the vast majority never reaching maturity, or if they do arrive at it, attaining it only to be starved or slain. As amongst men, competition is sharper between those of the same trade, so throughout the organic world the struggle is less severe between different species than between members of the same species, because these compete most fiercely for their common needs—plants for the same soil, carnivora for the same prey. But whether the battle is fought between allied or unallied species, the victory is never doubtful: it is assured to the plant or animal that has some advantage, however slight, which its opponent lacks. Among plants growing in a dry soil, those whose leaves have thicker hairs upon them will absorb more moisture from the air than plants with less hairy leaves, and competing successfully with these, will survive to transmit their advantageous variations. Again, such as are better able to resist the depredations of burglarious insects by protection of thorny or prickly stems, or by nauseous taste, will thrive and multiply, while plants lacking these defences dwindle and become extinct. So with those which by showy colours of their flowers and sweeter nectar attract insects whose visits are desired as carriers of pollen from stamens to pistils. These secure propagation, while plants less attractive remain barren. The birds that are strongest on the wing reach the land whither they migrate, while the weaker perish by the way. The lions of sharper sight and more supple spring, the wolves of keener scent,

secure their prey, while the feebler members starve. It is with man as with the organisms below him: the quickest in intellect, and those with greater power of endurance, distance the weak or the stupid, who fall behind, and finally slip out of the ranks altogether. Moreover, the battle of life is carried on within as well as without. The germs of countless organisms swarm in our food and drink, and in the air we breathe, bringing disease and death; but in every healthy body they are pounced on and devoured by wandering cells repelling the invading bacilli at the outposts before they can enter and poison the blood. Throughout the universe it is antagonism everywhere and always.

An important part in the struggle for life is played by what, for convenience sake, is called 'mimicry' or resemblance in outward appearance, shape, and colour between members of widely distinct families; and by what is also included under the term 'mimicry,' namely, 'protective coloration,' or resemblance between an animal and surrounding objects. For the more closely that an animal approximates in general appearance to its surroundings, the easier does it escape detection by its pursuer, and the easier does it avoid the notice of the prey which it pursues. In conformity with this we find that most animals are protectively coloured, while those which lack this are so constituted as to render such protection needless.

Thus is explained the white colour of certain arctic animals in winter; the stripes upon the tiger, which, parallel with the vertical stems of bamboo in the jun-

gle, conceal him as he stealthily nears his prey; the brilliant green plumage of tropical birds; the leaf-like form and colours of certain insects; the dried twig-like form of many caterpillars and of green snakes suspended from branches; the bark-like appearance of tree-frogs; the harmony of the ptarmigan's summer plumage with the lichen-coloured stones



WALKING-STICK INSECT.

on which it sits; and of the moth's wing with the fallen leaf on which it lies motionless; the dusky colour of creatures that haunt the night; the bluish transparency of animals which live on the surface of the sea; the gravel-like colour of flat-fish that live at the bottom; the gorgeous tints of those that swim among the coral reefs; even the protective coloration of eggs, cocoons, and countless other examples.

Among the secondary causes of modification of

species among animals Darwin gives prominence to 'sexual selection,' or the struggle between males for the possession of females; the result being that the stronger males secure mates, and transmit the qualities which have given them the mastery to their offspring. Every farmyard combat illustrates the truth of Schiller's poetry:—

> Meanwhile, until Philosophy
> Sustains the structure of the world,
> Her workings will be carried on
> By hunger and by love,

and among the larger animals—as stags and deer, and notably sea-lions, the deadliest combats take place at certain seasons for possession of the females. But there is competition less fierce in character, if not less fatal to the weaker or unendowed, when strength gives place to grace of form, brightness of colour, and witchery of song, and the females make choice of the male who by his beauty, colour, odour, or voice, attracts them most, or who, as among the highest species, has wealth or good social position. These last condone even infirmity and ugliness.

6. *Natural selection tends to maintain the balance between living things and their surroundings. These surroundings change; therefore living things must adapt themselves thereto, or perish.*

In treating of the obscurity which hangs around the ultimate causes of variation, stress has been laid on the ceaseless and elusively complex interplay between organisms and the medium which surrounds, quickens, and nourishes them.

It has been shown already that the *touch* of that medium was the first quickener of variation in the rise of the earliest approach to unlikeness at the surface, as in the membranous film which envelops the lowest life-forms, and, among the higher animals, in the gradual specialisation of lines of communication — the nervous system and sense organs — with the outer world from infoldings of the skin. The diffused sensitiveness to smell, light, and sound became localised, the sense of touch remaining general over the body-surface, except where horny skin is secreted. Obviously, therefore, the tendency to vary which inheres in living things being stimulated by interaction between them and their surroundings, the degree in which variations are useful to living things—*i.e.*, in enabling them to win in the universal struggle for food and place—determines, under the action of natural selection, their survival.

The slow but ceaseless changes in things without have involved adaptive changes in all organisms except the lowest. Seemingly, all things remain as they were from the beginning. The range of our experience is too narrow, the time since scientific observation of nature began is comparatively so recent, the changes in living things often so beyond direct detection, that we cannot wonder at people's reluctance to accept the theory that the countless species of plants and animals which have succeeded one another have a common descent, through infinite modification, from structureless germs. And, in fact, not only is life vastly older than any record of

it, but the fossil-yielding rocks supply no key to the origin of the leading groups, whose representative types of to-day are so little altered that every fossil as yet found can be put into existing classes. Professor Huxley remarks that 'the whole lapse of geological time has thus far yielded not a single new ordinal type of vegetable structure;' and although 'the positive change in passing from the recent to the ancient animal world is greater, it is still singularly small.' The variation in ordinal type of animal structure is only about ten per cent. of the whole.

Yet we know that nothing is rigid; the earth records the gradual ascent of life-forms in structure, and the changes in its crust, in a scripture that cannot be broken. The agencies within, and the far more potent agencies without, that have wrought those changes, pursue without pause their slow and sometimes sudden working. The earth itself speeds through space, heedless of the freight of life that throbs and struggles on its surface, and that at last is laid to sleep in its bosom; careens and brings the seasons in their sureness; spins and gives, unfailing, the glory of the sunrise and the sunset; and, in periodic changes of its orbit, crowns at one epoch its northern pole with vines and oaks and water-lilies, and at another epoch covers it with impassable ice.

Changes of climate and level, with the alterations in soil which they bring about, profoundly affect food and the power to obtain it. And the necessity for food being a strong—indeed, the strongest—stimulus to motion, the organism which the more readily

adapts itself to the changed conditions, or is better equipped to resist them, wins in the struggle. The new functions to be discharged involve changes in structure, because the organs exist for the work which they have to do, not the work for the organs. Moreover, changes which arise in the structure are not limited to one part, the whole organisation being, in Darwin's words, 'so tied together during its growth and development, that when slight variations in any one part occur, and are accumulated through natural selection, other parts become modified.' Then there are the changes wrought after long lapses of time by use and disuse, in the one case leading to the development of organs, in the other case to their decline. But few, if any, of the many changes induced in organs by their use or disuse on the part of the animal are transmitted; they die with the individual in which they occur. Like mutilations of parts of the body, which are practised through successive generations of individuals, they are powerless to affect the type.

It is to natural selection that we must more often refer modifications which, appearing as relics of structure common to large groups, have a specious look of being due to individual use or disuse. Take the familiar example of the true whale. The epitome of its ancestry which the embryo presents reveals its descent from land mammals having short fore and hind limbs, scanty covering of hair, broad beaver-like tails, teeth of different shape, and well-developed sense-organs, especially of smell. These forefathers

of the whale probably lived in marshy districts, and, being omnivorous, sought their food in both swamp and shallow water, but as conditions more and more adverse to life on land supervened, they were gradually modified under the action of natural selection into dolphin-like creatures, living in fresh water, and at last finding their way into the ocean, from which the huge sea-lizards of earlier epochs had disappeared, leaving these leviathans scope 'to play therein.' Hence are explained the adaptive changes of structure: the fore limbs were modified into flippers enclosed in a fin-like sac, but retaining the bones corresponding to like structures in other mammals, as in the arm of man, the wing of the bat, and the fore leg of the horse. Traces of the hind legs may be detected in a few species; the tail, which acted as a powerful swimming organ, became divided into two lobes; the head became fish-like in shape; the seven bones of the neck, common to most mammals, grew together; the skin became hairless; and the teeth, which appear in the young of the true whale but are never cut, gave place to hanging fringes of whalebone, in the meshes of which the animal entangles the minute organisms it feeds upon. In the seal, which is the modified descendant of land flesh-feeders, the hind legs have been developed, while the tail remains rudimentary.

The explanation is that both whales and seals are the gradually modified descendants of ancestors who, in virtue of their favourable adaptation to altered conditions, survived under the agency of natural selection,

while the majority, being unfit or less adapted, perished.

Variety of readjustment to altered surroundings, through like causes, resulting in progress in some directions and in stagnation in other directions, is further evidenced in existing modifications of the common mammalian type. We find one large group —the plant-feeders—developing organs suited to their functions, as teeth for grinding instead of for tearing, large stomachs, and horny or bony structures for combat, the evolution of which in the deer's ancestry is recapitulated year by year in the individual from the boss to the noble branching antlers. In the flesh-feeders we find that higher intelligence which the stealthy or open pursuit of other animals required, economy of bulk, great muscular strength united to quickness of action, and teeth and claws adapted for attacking and readily seizing prey.

In both groups we find progression of parts which in the Primates are well-nigh stationary. Among this group, limbs, teeth, and organs of digestion have all been slightly modified, and no organs of defence or attack developed. The explanation is that these animals, being unable to compete with the larger mammals, took to living in trees, which induced few variations of bodily structure, the most important being opposable thumbs and great toes for grasping. But the need for alertness against foes sharpened their wits, and the need of combination quickened the social instincts, so that the energy which in the flesh-feeders and the plant-feeders was stored in *limb* and

muscle was diverted in the Primates to development of *brain.* They thus escaped the limitations of one condition, which determined the development, say, of lions and rhinoceroses in a given direction, and they preserved the power to adapt themselves to very diverse conditions. Whichever among the arboreal creatures possessed any favourable variation, however slight, in structure of brain and sense-organs, would secure an advantage over less favoured rivals in the struggle for food and mates and elbow-room. The qualities which gave them success would be transmitted to their offspring, the distance gained in one generation would be increased in the next, brain-power conquering brute force, and skill outwitting strength.

And while some of them remained arboreal in habits, never moving easily on the ground, although making some approach to bipedal motion, as seen in the shambling gait of the man-like apes, others developed a mode of walking on the hind limbs which entirely set free the fore limbs as organs of support, and enabled them to be used as organs of handling and throwing. Whatever were the conditions which permitted this, the enormous advantage which it gave is obvious. It was the *making of man.* His bipedal and erect position involved exchange of tree-life for life on the ground, bringing him into new relations with his surroundings, and ultimately giving him the mastery over them. That the completely erect posture was acquired relatively late is shown, among other ways, in the crawling of the infant on all fours long after

birth and in the preference of the adult for sitting down. And that the erect position was an adaptation is proved in its leaving vital parts of the body exposed to dangers, against which man's ingenuity of brain has to devise protection.

We see in lower animals, as the elephant, the monkey, the opossum, and the parrot, that their power to grasp an object by reason of their prehensile organs, and thus to learn something about its nature, raises them in the scale of intelligence; and when we find in man a yet more perfect instrument to carry out the behests of his brain, we may see in the interaction of *brain* and *hand* a main factor in his development. The survival of the great toe as a grasping organ is seen among lower races: negroes seize branches with it, and the Chinese row with it. The structural differences between man and the highest apes are insignificant; the impassable chasm lies in his larger and more complex thinking apparatus. The action of natural selection became restricted, except in minor changes, as of the jaw, to his mental faculties. Yet even in brain-structure the differences between him and the chimpanzee are slight when compared with the differences between the brain of the chimpanzee and the lemur. It is in the deeper furrows and the more intricate convolutions that the distinction lies; but even here the gap between civilised and savage man is greater than that between the savage and the man-like apes. Therefore, in following evolution to its highest operations and results, the comparison lies between the several races of mankind.

Darwin says that he does not believe it possible to describe the difference between savage and civilised man. 'It is the difference between a wild and tame animal; and part of the interest in beholding a savage is the same which would lead every one to desire to see the lion in his desert, the tiger tearing his prey in the jungle, and the rhinoceros wandering over the wide plains of Africa.' He describes the Fuegians, who rank amongst the lowest savages, as men, 'whose very signs and expressions are less intelligible to us than those of the domesticated animals—men who do not possess the instinct of those animals, nor yet appear to boast of human reason, or at least of arts consequent on that reason.' Such races are much nearer to the ape than to the European, and it is from like accounts of existing savages that we may form some rough picture of 'primitive' man.

Doubtless he was lower than the lowest of these—a powerful, cunning biped, with keen sense-organs (always sharper, in virtue of constant exercise, in the savage than in the civilised man, who supplements them by science), strong instincts, uncontrolled and fitful emotions, small faculty of wonder, and nascent reasoning power; unable to forecast to-morrow or to comprehend yesterday, living from hand to mouth on the wild products of nature, clothed in skin or bark, or daubed with clay, and finding shelter in trees and caves; ignorant of the simplest arts, save to chip a stone missile, and perhaps to produce fire; strong in his need of life and vague sense of right to it and to what he could get, but slowly impelled by common

perils and passions to form ties, loose and haphazard at the outset, with his kind, the power of combination with them depending on sounds, signs, and gestures.

Such, in broad outline, was probably the general condition of the earliest known wanderers, the rude relics of whose presence are found associated with the bones of huge extinct mammals in old river beds and limestone caverns (see page 38). As the successive deposits and their contents show, not till long ages had passed, bringing new and settled conditions, with knowledge of agriculture, metals, and other useful arts, do we find any marked progress among mankind. Even that progress, often checked in its zigzag course, and never an unmixed good, has been confined to a small minority of the species and to a narrow zone, while, compared to the antiquity of man, it is but as yesterday. The enterprise of the higher races has explored and utilised large tracts, and the pressure of population at the centres of civilisation has within quite recent periods vastly extended their periphery; but whole empires, like China, advancing to a certain stage, have, through isolation and the tyranny of custom or dread of change, stagnated, whilst the lowest races have remained unmodified, like the lowest organisms, and have more or less succumbed before the imported vices and the weapons of the white man. But the causes of arrest and of advance are alike complex: man, like every other living thing, is the creature of outward and inward circumstances, and many influences have worked in

the shaping of his destiny. Certainly, extremes of climate have been fatal to advance beyond a given stage; it is in the temperate zones that the incentives exist to continuous and indefinite progress.

In reviewing the several operations by which species have arisen, it is essential to bear in mind that natural selection is not causal, but only directive. It is powerless to bring about the slightest variation in organisms; it is all-powerful to preserve variations 'beneficial to the being under its conditions of life; . . . it can do nothing until favourable individual differences occur, and until a place in the natural polity of the country can be better filled by some modification of some one or more of its inhabitants.' Moreover, since it tends to establish balance between life and its surroundings, it does not imply all-round development of the higher from the lower. Its key-note is adaptation. Hence are explained both advance, degradation, and 'atavism' (Lat. *atavus*, an ancestor), or reversion to ancestral types.

The parasites notably, the sea-squirts and the marvellous rotifers, are examples of recession. Nor these alone; the history of mankind, with its degenerate races, Bushmen, Fuegians, and, perhaps, Australians; with its relics of ancient civilizations, whose art we can only feebly imitate, and whose types of manliness we cannot hope to excel; furnishes its monitions of the lethargy and love of ease which precede the downfall of peoples.

Examples of persistence of type are supplied in the unaltered condition of the simplest forms since the

appearance of their earliest known representatives. Their simplicity has been their salvation. A high organisation brings with it many disadvantages, for the more complex the structure the more liable is it to get out of gear. We cannot have highly convoluted brains, and at the same time digestive organs simple and renewable like those of the sea-cucumber. Death is the price paid for complexity.

Of the propositions expounded in the present chapter this is the sum:—No two living things are exactly alike. Their inherent tendency to vary is stimulated by their surroundings, on which all life depends, and to changes in which they must adapt themselves or perish. Every living thing transmits its qualities, and therefore, among them, its variations, to its offspring; the more useful the variation, the better is the plant or animal equipped in the struggle for life. For as all living things tend to multiply so rapidly that the earth would be too small in a very short time for a single species, a fierce and ceaseless struggle is waged, chiefly between the same species, for food and place. The result is that by far the larger number never reach maturity, or are killed and eaten. In the long result variations give rise to new species.

The only assumption at the base of Darwin's theory is that sufficient time has elapsed since the beginning of life for the development of all past and present species of plants and animals from a common ancestry. As to the age of the earth, more especially as a fit and possible abode of life, geologists and phys-

icists are practically, now agreed. The geological estimate rests chiefly upon the rates at which the deposit of sediment, or the wearing away of soil by rain and rivers, is going on ; but allowing for the probable action of more rapid causes of change, it favours the lapse of not much less than one hundred million years since the earliest life-forms appeared and the oldest stratified rocks began to be laid down. This is about the period that the physicists, reasoning from the origin and age of the sun's heat, the rate of the earth's cooling, the action of tidal friction as a skid, on its rotation, and other data, are willing to allow. But, of course, all calculations are only approximate.

CHAPTER X.

PROOFS OF DERIVATION OF SPECIES.

THE evidence supplied by living things in support of their common descent is fivefold: viz. 1, by embryology, or likeness in their beginnings and development; 2, by morphology, or structural likenesses; 3, by their classification; 4, by their succession in time; and 5, by their distribution in space.

1. *Embryology.* — The eggs or germs from which all organisms spring are, to outward seeming, exactly alike, and this likeness persists through the earlier stages of all the higher animals, even after the form is traceable in the embryo. Darwin quotes the following from Von Baer, the discoverer of this remarkable fact:

'In my possession are two little embryos in spirit, whose names I have omitted to attach, and at present I am quite unable to say to what class they belong. They may be lizards, or small birds, or very young mammalia, so complete is the similarity in the mode of formation of the head and trunk in these animals. The extremities, however, are still absent in these embryos. But even if they had existed in the earliest stage of their development we should learn nothing, for the

feet of lizards and mammals, the wings and feet of birds, no less than the hands and feet of man, all arise from the same fundamental form.' In further evidence of this interrelation of living things, their embryos, as we have seen, epitomise during development the series of changes through which the ances-

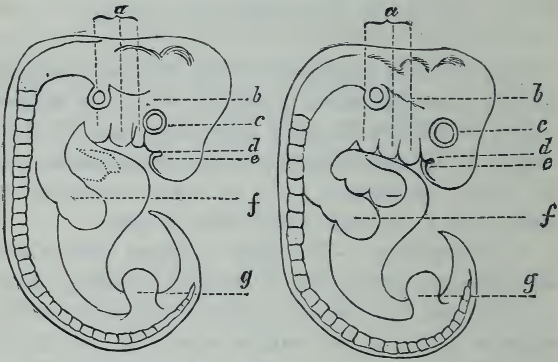


FIG. 6.—DOG (4 weeks). MAN (4 weeks).
Magnified about 7 diameters. (After Haeckel.)
a, gill-arches; *b*, mid-brain; *c*, eye; *d*, nose; *e*, fore-brain; *f*, fore-leg; *g*, hind-leg.

tral forms passed in their ascent from the simple to the complex; the higher structures passing through the same stages as the lower structures up to the point when they are marked off from them, yet never becoming in detail the form which they represent for the time being. For example, the embryo of man has at the outset gill-like slits on each side of the neck like a fish; these give place to a membrane like

that which supersedes gills in the development of birds and reptiles; the heart is at first a simple pulsating chamber like that in worms; the back-bone is prolonged into a movable tail; the great toe is extended or opposable, like our thumbs and like the toes of apes; the body three months before birth is covered all over with hair except on the palms and soles. At birth the head is relatively larger and the arms are relatively longer than in the adult; the nose is bridgeless; both features with others which need not be detailed, being distinctly ape-like. Thus does the egg from which man springs, a structure only one hundred and twenty-fifth of an inch in size, compress into a few weeks the results of millions of years, and set before us the history of his development from fish-like and reptilian forms, and of his more immediate descent from a hairy, tailed quadruped. That which is individual or peculiar to him, the physical and mental character inherited, is left to the slower development which follows birth.

Besides the past history which the embryo recapitulates, there are the rudimentary structures of which relics remain as witnesses to the former close connection of organisms. Among these are teeth in fœtal whales, remnants of hind limbs in certain snakes, wings under the wing-cases of insects that do not fly, rudiments of pointed ears and of a third eyelid in man, abortive stamens in plants, as in the snapdragon, and so forth. Except as evidence of the modification of life-forms in which they occur from other life-forms, and of persistency of type, these vestiges of

organs are meaningless; the functions they once discharged have long ceased, being exercised only in other and allied living things where they are found fully developed.

2. *Morphology.*—Large groups of species, whose habits are widely different, present certain fundamental likenesses of structure. The arms of men and apes, the fore-legs of quadrupeds, the paddles of whales, the wings of birds, the breast-fins of fishes, are constructed on the same pattern, but altered to suit their several functions. Nearly all mammals, from the long-necked giraffe to the short-necked elephant, have seven neck-bones; the eyes of the lamprey are moved by six muscles, which correspond exactly to the six which work the human eye; all insects and crustacea—moth and lobster, beetle and cray-fish—are alike composed of twenty segments; the sepals, petals, stamens, and pistils of a flower are all modified leaves arranged in a spire. Such facts point only one way.

3. *Classification.*—It has been shown that all plants fall into two main groups, the flowerless and the flowering, and that all animals may be reduced to three types: (1) those without body cavity; (2) those with body cavity; (3) those with digestive cavity separate from body cavity. And the general likenesses of structure upon which division into sub-kingdoms is based having been given in the chapters on existing life-forms, it here suffices to repeat that the only true mode of presentment, both of the life that is, and that was, is that of a tree with short trunk, in-

dicating common origin of the living from the non-living, and divided into two large trunks representing plants and animals respectively. From each of these start large branches representing classes, the larger branches giving off smaller branches representing families, and so on with smaller and smaller branches representing orders and genera, until we come to leaves as representing species, the height of the branch from which they are hanging indicating their place in the growth of the great life-tree. (See Diagram, p. 90.)

4. *Succession.*—Each formation has its peculiar groups of fossil remains representing the life-forms of the period; the older the rock, the simpler are its organic contents; and, what is of no mean importance, although transitional forms are from their nature fewer and less permanent than forms which have arrived at balance with their surroundings, the fossil-yielding rocks have disclosed the existence of several hitherto missing links between species. Reference has been made to the proofs of the descent of the one-toed horse of to-day, with his knee corresponding to our wrist or ankle, from the five-toed *Phenacodus* found in the Eocene beds of North America, and to the connecting link between birds and reptiles supplied by the archæopteryx. To these may be added, among others, the links between pigs and hippopotamuses in the anoplotherium; between tapirs, horses, and rhinoceroses in the palæotherium; between seals and whales; between sloths and beavers; between lemurs and man-like apes; and in the Devonian strata forms occur which are considered intermediate between gan-

oids and mud-fishes. Thus one by one the 'missing links' in the chain of life are being found; in fact, none of any great importance among such as may reasonably be looked for are absent. Those who ask for the 'missing link' between man and ape only parade ignorance. Both these animals descended from a common ancestry whence they branched off in different directions, and in any remain of man's progenitors the brain and suchlike soft parts as would throw light on their differences from man-like apes would have perished long ago. And further, the 'links' between the great apes themselves are missing.

5. *Distribution.*—To know something of the complicated subject of the geographical distribution of plants and animals we must study the past as well as the present, and learn both from geologist and astronomer, the one telling us of the shiftings of land and water, and the other accounting for the great climatal changes that have swept over the globe.

Every living thing has its definite area of range: the sloth is peculiar to America; the hippopotamus to Africa; the chamois to the Alps. The higher we climb, the hardier and more stunted is all vegetation; tropical plants perish in cold or even temperate zones; Arctic plants wither under the equator; while a vast number of plants flourish only in water, the primeval life-home. Among animals a few, notably man and the cat genus, have spread themselves well-nigh everywhere, but as a rule certain life-forms—and this holds good of their fossil representatives also—are restricted

to certain regions. Hence the land has been divided into life-regions corresponding to that distribution, and the water into life-regions measured by the limits of depth at which marine forms are found. Speaking broadly, the plants and animals of countries in unbroken connection resemble one another, while those of countries remote or cut off are unlike. But although, at first sight, climate and separation would appear to account for this, there are likenesses and unlikenesses which are not to be thus explained. In fine, exceptions meet us at every turn. Great Britain and New Zealand are much alike in general conditions, yet the life-forms of New Zealand, now being fast supplanted by aliens, are the little-altered survivors of plants and animals once dominant over the globe. On the other hand, as Mr. Wallace tells us, the Englishman visiting Japan finds its woods and fields tenanted by the singing birds familiar to him at home. Tapirs, whose origin in the north-western parts of the Old World is indicated by their fossil remains in Miocene beds, are now separated by nearly half the globe's circumference, being found only in South America and Malacca, while the man-like apes are found only in West Africa and Borneo.

But puzzling and seemingly capricious as is the distribution of life, the general causes are not far to seek.

Distribution is due to the slow but ceaseless migration and transport of living things rendered necessary by their rate of increase. While climate has much to do with it in compelling organisms in proportion to their power of dispersion, to shift their quarters, the

struggle for life between them has had more influence still, so that the past and present habitats of plants and animals throw welcome light not only on changes in the relations of land and water, but also on the origin of species.

Where unallied forms are found on the same continent we may infer that the physical barriers between them have been permanent through long periods; where allied forms which are unable to cross the seas are found in lands now separated, as in Britain and Japan, in South Europe and North Africa, we have evidence of former union. The degree in which life-forms have been modified gives some key to the remoteness of that union; as, for example, when we find more ancient types in New Zealand than in Australia, and more ancient types in Australia than in Madagascar.

Islands afford important aid in the study of the intricate problem of distribution. They are of two kinds, continental and oceanic. The continental, as the British Isles, Japan, ancient Madagascar with its lemurs, and New Zealand with its wingless birds and Hatteria lizard, have been broken off from the mainland. The oceanic, as the Azores and Sandwich Islands, are of volcanic or coralline formation, and depend for their life-forms upon their relative position to the mainland, and also to the winds and ocean currents that prevail. Exclusive of animals introduced by man, they are found destitute of frogs and other batrachians; also of mammals, bats excepted; the explanation being that sea-water kills frogs and toads

and their spawn, and that only flying animals can cross the ocean. For this reason bats, at least the insect-eating species, are found everywhere, except at the poles; the range of birds, although defined, is much wider than that of all the larger and wingless land animals, while that of insects is of course helped by their great powers of flight, and their extreme lightness, which carries them on the wind enormous distances.

Isolated islands like St. Helena are peopled with waifs and strays from all quarters, while in continental islands like our own the life-forms are, for the most part, identical with those of the nearest mainland. But here, again, exceptions exist. The islands of Bali and Lombok in the Malay Archipelago, although only fifteen miles apart, differ far more from each other in their birds and quadrupeds than do England and Japan, the birds being extremely *unlike.* As shown by the deep soundings, Bali belongs to the Indian region, and Lombok to that zone of 'living fossils,' the Australian region. Australia contains only the lowest mammals, as duckbills and kangaroos—for there is little doubt that the dingo or wild dog was introduced by man—witnessing to its severance from Asia millions of years ago during the Secondary epoch. It is an ancient and little altered fragment, preserving as in a museum the types of plants and animals which were then dominant on the great shifting land areas, and from which the higher forms have been developed.

Oceanic islands, with their population of birds, flying insects, and a few creeping things, are the refuge

spots of castaways. Strange are the ways and means of dispersal. Winds waft the light seeds of plants to great distances; and currents drift to off-shores icebergs laden with earth and seeds, or masses of floating vegetation, sometimes so matted with soil as to form island rafts with trees upstanding, and carrying with them not only numbers of grubs and eggs of insects, but even large animals. Birds are important agents in plant distribution, transporting seeds embedded in dirt sticking to their feet or beaks, or undigested seeds and stones of fruits which are passed through their bodies.

Very important also, although more remote in its ultimate results, is the agency of man, especially of civilized races, in the distribution of life. Both with and without intent he distributes and destroys, as his needs or caprices demand. Clearing forest, draining lake and bog, reclaiming land from sea, or uniting ocean with ocean, he disturbs, or mingles, or kills their life-forms. He imports strange plants and noxious insects in his merchandise; he transports the healing cinchona plant from Peru to India, or the salmon ova from our native streams to the rivers of Australia; and to him is due the re-introduction of the horse into America, which had been extinct there long before the arrival of Columbus. The *hortus siccus* of a botanist may accidentally sow seed from the foot of the Himalayas on the plains that skirt the Alps; when the cases containing the artistic treasures of Thorwaldsen were opened in the court of the museum at Copenhagen where they are deposited, the straw and grass employed in packing them were scattered upon the

ground, and the next season there sprang up from the seeds no less than twenty-five species of plants belonging to the Roman Campagna.

It surprises one to learn how many of our familiar flowers are foreigners which happy chance or wise intent have acclimatised. The daisy and the violet are natives, but not the laburnum and jasmine, nor

> Sweet William with his homely cottage smell,
> And stocks in fragrant blow.

While needless destruction has often followed in the wake of man, as he kills out of sheer wantonness, or seeks profit by gratifying the cruel freaks of fashion, his enterprise and needs have, on the other hand, rid the earth of harmful and baneful plants and animals, produced food and clothing from wild species, luscious fruit from sour and dwarfed varieties, and developed domestic animals, the dog probably earliest of all, from the fierce beasts of the forest and the field.

Enough has been cited to show that no preordained scheme of fitness for their several habitats has placed plants and animals where they are found. Remembering what has been said about the probable polar origin of life, we are prepared to find that, so far as most of the higher forms are concerned, our best authorities, with Mr. Wallace at their head, incline to the theory of their development in the Euro-Asiatic continent when the temperature was comparatively warm from the pole to the antipodes. The wave of migration rolled over the Old World far

south by routes now long submerged, and into the New World, where other life-forms appear to have been developed, by a northerly route. One among several proofs of the existence of an old land connection between North America and Europe is supplied by the musk-sheep (or musk-ox), which flourished ages ago in Eurasia, and is now confined to Greenland. And it is interesting to note that the path taken by some birds in their migrations, the leading motive of which is probably the search after food in sunnier climes whither inherited instincts take them, gives further clue to other ancient land connections. Incapable as they are of crossing the wide oceans, we find them migrating between Europe and Africa by way of Greece, Malta, and Gibraltar, the three points at which the two continents were formerly united. They cross the seas, following some long-lost land line which their ancestors have taken for countless seasons.

Wide-spread as is the distribution of the races of mankind, they are probably of common origin. All of them being fertile with one another, they are to be classed as varieties of one species, whose physical and mental differentiations from their nearest congeners, the highest apes, had been acquired before their dispersion. The modifications which exist have been developed through the potent agency of natural and sexual selection acting upon variations induced by diverse conditions; conditions which have surrounded man in virtue of his migrations from pole to pole, and which have called his industry and resource into

full play. Perhaps the most striking illustration throughout history of the rapid rise of a variety is supplied by the Anglo-American race, the vigour of which may be primarily due to the blending of many bloods, pre-Celtic, Celtic, Teutonic, and Scandinavian, in its ancestry.

'That many and serious objections may be advanced against the theory of descent with modification through variation and natural selection I do not deny. I have endeavoured to give them their full force.' Thus speaks Darwin, and the sixth, seventh, and tenth chapters of the 'Origin of Species' are proof of this. He shirked no difficulty, and in laying stress upon whatever told against his theory he made its foundations more sure. One great, but unduly overrated, stumbling-block—the absence of intermediate forms in the fossil-yielding rocks—has been removed by the discovery of many more connecting links in the long chain of life than could be expected when we take into account the small minority of ancient forms which have escaped the havoc of the past, and when we remember how much smaller are the chances in favour of the preservation of the more fragile, rare, and unstable transitional forms than of the species which they connect.

Another leading objection, drawn from the barrenness of hybrids—as, *e.g.*, of the mule—loses much of its force in view of the numerous examples to the contrary, both in plants and animals, as amongst genera of the thistle and of the laburnum, and as in the cases of fruitful hybrids of sheep and goats in Chili. But,

as against natural selection, the real difficulty lies in the interbreeding of species developed by selective breeding from a common stock. For example, the different species of pigeons have been developed from the wild rock-pigeon, and these are fertile with one another, which would seem to tell in favour of the fixity of species, unless the carrier, pouter, and tumbler are, after all, to be regarded only as varieties or subdivisions of species. The matter, however, is too abstruse for these pages, and, moreover, it has no weight as against the theory of derivation. We know very little as to the complex conditions ruling fertility and barrenness; we know that the reproductive organs are peculiarly sensitive to altered habits and surroundings; and we know, further, that it is through changes in those organs that the barriers to interbreeding have arisen, and the consequent multiplication of countless intermediate varieties been arrested. Happily, the Darwinian theory, like all true scientific theories, has no fatal element of rigidness in it. It admits of alterations in detail at the behest of fresh facts, and of such correction of proportion as time alone gives to things new and near. But the truth of the great theory of Evolution of which it is a subordinate part will thereby stand out the clearer, and the full accord of past and present to the oneness of things appear more manifest.

CHAPTER XI.

SOCIAL EVOLUTION.

1. *Evolution of Mind.*—If the theory of Evolution be not universal, the germs of decay are in it. And here we pass from what is interesting to what is of serious import for us, because if the phenomena of mind are not capable of the like mechanical explanation as the phenomena of stars and planets, and of vegetable and animal life, Evolution remains only a speculation to fascinate the curious. It can, in that case, furnish no rule of life or motive to conduct, and man, 'the roof and crown of things,' would be the sole witness against their unity and totality. If there be in him any faculty which is no part of the contents of the universe, if there be anything done by him which lies outside the range of causation, then the doctrine of the Conservation of Energy (see page 6) falls to pieces, for man has the power to add to that which the physicist demonstrates can neither be increased nor lessened.

The ground already covered need not be retrodden to show that man is one in ultimate beginnings, and in the stuff of which he is made, with the meanest flower that blows, and that in mode of develop-

ment from the egg to the adult state there is exact likeness between him and other mammals. But some repetition of the process of mental development from the lowest life-forms to the highest is needful.

'Structure for structure,' remarks Professor Huxley, 'down to the minutest microscopical details, the eye, the ear, the olfactory organs, the nerves, the spinal cord, the brain of an ape, or of a dog, correspond with the same organs in the human subject. Cut a nerve, and the evidence of paralysis, or of insensibility, is the same in the two cases; apply pressure to the brain, or administer a narcotic, and the signs of intelligence disappear in the one as in the other. Whatever reason we have for believing that the changes which take place in the normal cerebral substance of man give rise to states of consciousness, the same reason exists for the belief that the modes of motion of the cerebral substance of an ape, or of a dog, produce like effects.'

Let us begin, however, at the bottom of the life-scale. The lowest things, being organless, or alike all over, respond to touch, 'the mother-tongue of all the senses,' in every part, simply changing their shape from moment to moment. A step higher we find forms in which unlikenesses in parts begin to show themselves—*e.g.*, in the formation of a layer at the surface; and here the responses to the stimuli, as they are called, become localized, because the movements set up by the stimuli take place, like all modes of motion, along the lines of least resistance. These movements give rise to changes in the structure of the

organism, driving the molecules out of their places, and, following in incredibly rapid succession, finally lay down permanent nerve-tracks, built up of the more sensitive parts of the skin. Practice makes perfect; and, as the result of their incessant repetition, the lowest and simplest nerve-actions, known as *reflex*, take place automatically in plants and animals. Such are the contractions of an amœba or of the leaves of a sensitive plant; the shutting up of an oyster when the shell is touched; breathing; the action of the heart; winking of the eyes—in short, all actions which are performed unconsciously, and repeated in virtue of the tendency to do them being innate in the structure which each organism inherits from its ancestors. Besides these natural reflex actions, there is a group of artificial reflex actions which our higher intelligence enables us to acquire, as the arts of reading, playing instruments, etc.

Instinct is a higher form of reflex action. The salmon migrates from sea to river; the bird makes its nest; or migrates from one zone to another by an unvarying route, even leaving its young behind to perish; the bee builds its six-sided cell; the spider spins its web; the chick breaks its way through the shell, balances itself, and picks up grains of corn; the new-born babe sucks its mother's breast—all in virtue of like acts on the part of their ancestors, which, arising in the needs of the creature, and gradually becoming automatic, have not varied during long ages, the tendency to repeat them being transmitted within the germ from which insect, fish, bird, and man have

severally sprung. Touching on larger matters for a moment, even the so-called necessary truths and innate ideas of the mind, as of time and space, take their place among transmitted experiences. 'Being,' as Herbert Spencer says, 'the constant and infinitely repeated elements of thought, they must become the automatic elements of thought of which it is impossible to get rid.'

More than a century ago Gilbert White remarked that 'the maxim that defines instinct to be that secret influence by which every species is compelled naturally to pursue at all times the same way or track without any teaching or example, must be taken in a qualified sense, for there are instances in which instinct does vary and conform to the circumstances of place and convenience.' Herein that delightful observer, perhaps without suspecting what he was conceding to the brute, indicates where instinct is in process of passing into *Reason*. For the main difference between the two is that while the one is done because the animal cannot help doing it, and has no knowledge of the relation between the means and the end, the other is the conscious adjustment of means to ends—selection as the result of reflection. In the one there is no pause; in the other there is a measurable interval; the stimuli to action are more complex and less rapid, giving time for that perception of likenesses and unlikenesses in things—therefore, of their relationships, which is essential to rational action.

The lower animals start fully equipped for their functions; their actions are reflex and unvarying

from birth to death. But in the higher animals the same mental processes are apparent as in man. Like him, they learn from experience; distinguish between the various properties of things; and as Hume says, 'infer that the same events will always follow from the same causes.' There is not a faculty of the human mind which is not possessed in lesser or greater degree by them; oftenest in lesser degree, sometimes in larger degree, as in the many proofs of affection and devotion shown by animals which put man's selfishness to shame. Where some of the highest animals make a certain approach to him is in their passage through a period of helpless infancy, because the brain and connecting apparatus are not complete at birth; and in this lies the explanation of the capacity for receiving instruction and for profiting by experience which reaches its fullest development in man. And it is because the knowledge that is gained, and the habits that are acquired in early life, abide with us, determining character, that the importance to ourselves and to others of learning what is true, and of cultivating what is best, is paramount. Vast, therefore, as are the differences between the highest and lowest mental actions, there is no break in the series which, starting with the reflex movements of an amœba or of a carnivorous plant, advances along the line of animal instinct and intelligence, and ends with the complex movements of the brain of civilised man, with its infinite modes of response to infinite stimuli.

2. *Evolution of Society.*—Like every other species,

man multiplies beyond the means of subsistence. Civilised races are more prolific than savage races. Under prosperous conditions they double their numbers in a quarter of a century, a rate at which the present population of the United States alone would in six hundred and fifty years cover the terraqueous globe so thickly that four individuals would have to stand on each square yard of surface. Consequently the mortality of the human species, though far less than that of any other animal, is still enormous. It is computed that more than seven hundred million human beings are every century pounded back to nothingness without knowing that they ever lived, to which have to be added the vast number that die in early childhood, and the wholesale destruction of communities by wars, pestilences, famines, and catastrophes. In various ways natural selection weeds out the least fit; and although under civilised conditions the weak and diseased are coddled and even unwisely permitted to multiply their kind, this check is too local to affect the larger result, while that which the race might gain in physique by its removal is not to be compared to the loss that would ensue from the repression of the mercy and sympathy of which the world holds no superfluous store.

When the weeding process has done its utmost, there remains a sharp struggle for life between the survivors. Man's normal state, like that of every plant and animal, is one of conflict. It impelled his Tertiary ancestors, the man-like apes, to some form of

social life, because union was strength in the face of their inferior physique to other animals. The range of that unity remained narrow long after man, as we know him in the Ancient Stone Age, had gained lordship over the brute; the struggle between the various clusters of human creatures for food and other bodily needs was ferocious, and under one form or another, disguise it as we will, rages to this day. 'There is no discharge in that war.'

It may change its tactics, its weapons, and its arena; among advanced nations the military method may be more or less superseded by the industrial, and men may be mercilessly starved instead of being mercifully slain; but be it war of camps or markets, of ambitious rulers or of greedy traders, the ultimate appeal is to force of brain or muscle, and the hardiest or craftiest win. In some respects the struggle is waged more fiercely than in olden times, and is unredeemed by any element of chivalry then present in it. Moreover, the greater strength of man's emotions, with their insatiate craving for excitement, acting upon his inherited savage instincts, and, aided by his vigorous imagination, have made that struggle more terrible than any that rages between the lower animals. These fight for food and mates, not for the mere love of fighting. No brute ever tortured its kind, or gloated over the agonies of its prey, as man has tortured in fiendish glee the victims of his revenge, intolerance, and hate. True it is that peace has been wrung from pain, that war is a nation-builder; that slavery and superstition

have been agents of progress, whereby the many, through the sufferings and sacrifice of the few, have gained freedom, unity, and larger life; that in the death-struggle for food, curiosity, the mother of knowledge, has been awakened, never more to sleep; that in the fight for mates the germ of the highest and purest love of man for woman has been developed; that in the conflicts between tribes patriotism and hardy, generous virtues have been evolved; but when we count the cost—the miserable lives of unnumbered millions—all this would afford small content could we not note the signs of a happier lot for the many, and have hope that in the slow-footed years man's fuller knowledge of his fellow-men which intercourse between races ensures will subdue the feeling that makes him regardless of the weal of the weak, the erring, and the unfortunate.

The instincts which led him to combine with others were inherited from pre-human ancestors. 'There is,' wrote Gilbert White in 1775, 'a wonderful spirit of sociality in the brute creation, independent of sexual attachment;' and Darwin remarks that 'the social animals which stand at the bottom of the scale are guided almost exclusively, and those which stand higher in the scale are largely guided by special instincts in the aid which they give to the members of the same community; but they are likewise in part impelled by mutual love and sympathy, assisted apparently by some amount of reason.' In the degree that animals are social we find them higher in the scale, as ants, bees, and wasps among insects; and

among domestic animals, dogs, whose wild ancestors hunted in packs, as compared with cats, which inherit the solitary and wandering habits of their wild ancestors.

We do not know what the earliest social unions among mankind were like. Probably there were no family arrangements as we understand the term, but only various kinds of relations, more or less fugitive, between groups of men and women for maintenance and defence. The details, however, do not affect the fact of social intercourse, in which community of interest was the binding force. Impetus was given to more personal and permanent relationships by the longer period of infancy in man as compared with the same period in the man-like apes, in whom, again, it is much longer than in the lower monkeys. For that period of helplessness would evoke the loving care and pity of the parents, drawing them and the offspring together, and would develop those enduring and exalted relations between members of the same family which widened into tribal life. Struggles against common foes brought the bravest to the front as leaders; turbulent elements within involved the intervention and rule of the ablest; disputes called for the counsel and settlement of the wisest; and thus the rough foundations of law and order were laid. As the wants and capacities of the ever-growing community multiplied, the work done by a single pair of hands under rude conditions was divided among many; hence specialization of the people into classes, with all the complex duties of modern societies.

Carlyle says that the great man shapes the age in which he lives; Herbert Spencer says that the age shapes the great man. The processes are so complex and intermingled that both statements need qualification; some men, like Alexander the Great and Cæsar, have effected more change in the course of human history than centuries of slow development have brought about; nevertheless leaders of men are the products of past tendencies and present conditions, supreme to the extent that these operate in them in the highest degree; hence their control of the inferior majority for good or evil.

3. *Evolution of Language, the Useful Arts, and Science.*—Man is markedly separate from the highest brute, not only by his brain-power and his erect attitude, with its free command over the hands, but also by language. Not that the 'dumb' animals, as they are called, are all voiceless, many of them having no small or inexact gamut of sounds by which to express their thoughts and emotions. But although the love-calls of birds and the danger-cries of beasts may be not more unintelligible to us than the language of savages like the Fuegians, which Captain Cook compared to a man clearing his throat, the distinction abides that language, as the plastic symbol of ideas of unlimited range and complexity, marks the impassable gulf between the mental capacity of man and every other animal. Its origin lies in his need to communicate with his fellows; and but for it all attempts after social union, except of the lowest and most fleeting kind, would have been as the weaving of a rope of sand.

Words themselves reveal under analysis the history of their origin from a few simple root-sounds, which were instinctive cries or imitations of various natural noises very largely aided at the outset by signs and gestures. Speech is but one way of expressing thought; deaf mutes exchange ideas easily by gesture, which to this day is the sole mode of communication between certain wandering American Indian tribes, and largely supplements talk among the vivacious races of Southern Europe. We can never know what the first sound-signs were like, but their choice and currency obviously depended on the success with which they conveyed the meaning of those who invented them—a principle, of course, applicable to every stage of language, from the simple names of objects with which it began to the ultimate transfer of those names to abstract ideas. For all abstract terms have a concrete origin. The words just used evidence this: *abstract* means 'dragged away;' *concrete*, 'grown together.' Even the verb *to be* is made up of 'the relics of several verbs which once had a distinct material significance.' *Be* contained the idea of "growing;" *am*, *art*, *is*, and *are*, that of "sitting;" *was* and *were*, that of "dwelling," "abiding." From A to Z the dictionary is crowded with examples of the physical roots from which moral and intellectual terms have sprung. A *supercilious* man is, literally, 'one who raises his eyebrows' (Lat. *super*, above, and *cilium*, an eyelid): a *candid* man is the 'white' or 'spotless,' that word being cognate with the name *candidatos* given by Romans to office-seekers, who were dressed in white; a

sycophant, as we call a truckling person, means a 'fig-blabber' (Gk. *sykophantes*) applied to informers against the law-breakers who exported figs from Attica; a *calculating* man is literally one who counts with 'small stones' (Lat. *calculus*, a pebble); and so the list might run on. It is from mimetic sounds, with their boundless variety of modulation, that there have been developed not merely the scanty and shifting speech of the lower races, but the wondrously rich, copious, and ever-growing languages of civilized races from the sound-carriers of man's everyday wants, to the lofty ideas enshrined in prose and poetry, without which, now become the common intellectual wealth of nations through the arts of writing and printing, how poor and dwarfed would human life have been! Language, therefore, has followed the common law of evolution in advance from the simple to the complex, and proved itself one of the many instruments which the skill of man has perfected from raw materials as his social needs have impelled him and as his intelligence has increased.

And the like adaptation of means to ends applies to the development of the useful arts, as well as of those arts in which the head is more concerned than the hand. The primal needs of clothing and shelter, of weapons of war and of the chase—for sword and bow precede spear and hammer—the need, under more settled conditions, of implements for the household and the field, set man's wits to work to supplement and improve that which nature supplies in the rough. For if he is not the only tool-user, he is the only tool-

maker, among the Primates. Every instrument of his culture bears traces of its development from simpler forms; the spear and knife-blade from the sharp-edged flint flake; the saw from the jagged-edged flake; the matchlock from the crossbow; the woven fabric from the twisted grass; the plough from the stag's antlers or the tree branch; the mill from pounding stones; the ship from 'dug-out' trunk; the oar from the hands or feet as primitive paddles; the house from the sun-baked clay hut; or, as in China, modelled after the Tatar tent; the pyramid from the earth-mound or heap of burial stones; all art from imitation—the alphabet from picture-writing; sculpture and painting from rude scratchings on bone and horn; fictile ware of Sèvres from clay-smeared vessel; stringed instruments from the twang of the hunter's bow; wind instruments from the blast of his horn; in the words of Lucretius, 'the blowing into hollow stalks from the whistling of the zephyr through the hollows of reeds;' melody and dance from the impassioned chant of the savage, time-worked by yell and tantam; arithmetic from primitive perception of more and less; counting and measuring, as shown in our words cubit, ell, foot, hand, digit, span, fathom, and in cognate terms of other languages, from using the fingers, toes, and other parts of the body; geometry, or land-measuring, from early perception of space; all science from crude guesses about the causes and properties of things, as from illusions of alchemist and astrologer, which made attainment of the truth more possible to chemist and astronomer; and

so on through the whole range of man's social and intellectual development.

4. *Evolution of Morals.*—Man by himself is not only unprogressive, he is also not so much immoral as unmoral. For where there is no society there is no sin. Therefore the bases of right and wrong lie in conduct towards one's fellows; the moral sense or conscience is the outcome of social relations, themselves the outcome of the need of living. The common interests which impel to combination involve praise or blame of the acts of each individual in the degree that they aid or hinder the well-being of all —in other words, add to their pleasure or their pain; and this praise and blame constitute the moral code, the collective or *tribal conscience.* Society, like the units of which it is made up, has to fight for its life, and all primitive laws are laws of self-preservation. Tribal self-preservation is based on sympathy between the several members, and it is therefore the ultimate foundation of the moral sense; whatever is helpful to it is *right*, whatever is a hindrance to it is *wrong.* Although union involves limitation and restraint, so that the units can no longer do exactly as they like, self-interest comes into play, since a man best insured respect for his own rights by respecting the rights of others. Society is not possible where a man is not true to his fellow; there is, as the phrase goes, honour among thieves, probably even among savages as low as the Jolas of the Gambia, every one of whom does as he likes, the most successful thief being the greatest man. In that model of sound and clear rea-

soning,—so refreshing a contrast to the tedious word-mongering of most writers on ethics,—the chapter on the growth of the moral sense, in the 'Descent of Man,' Darwin points out how man's instinctive sympathy would lead him to value highly the approval of his fellows, and how his actions would be determined in a high degree by their expressed wishes; unfortunately, often by his own selfish desires. But while the lower instincts, as hunger, passion, and thirst for vengeance, are strong, they are not so enduring or satisfying as the higher feelings which crave for society and sympathy. And the yielding to the lower, however gratifying for the moment, would be followed by the feeling of regret that he had thus given way, and by resolve to act differently for the future. Thus at last man comes to feel, through acquired and perhaps inherited habit, that it is best for him to obey his more persistent impulses. It is this self-accusing feeling of remorse (literally *after-bite*), due to power of reflection on actions and motives, that makes the difference so profound between man and the lower animals, whose moral sense does not advance beyond the stage which commits or avoids certain acts according as they are remembered as pleasurable or painful to the creature itself.

Special value would be set by the tribe upon brave and unselfish acts as contributing to the common weal; praise and honour would reward the doer, encouraging that love of the tribe in which lay the germ of love of country. For he who is not a good citizen cannot be a true patriot, and he who holds

not his fatherland dear can never become a well-wisher to mankind. The conceptions which these larger interests involve, are, however, of very slow growth; for a long time the feeling of rightness and wrongness was limited to acts harmful or helpful to the tribe; in fact, that which was a crime within its borders became a virtue, and even a duty, outside them. Cæsar says that among the ancient Germans 'robberies beyond the bounds of each community have no infamy, but are commended as a means of exercising youth and lessening sloth,' and this description still applies not only to barbaric peoples, but has its survival in the slowly decaying prejudices of civilized nations.

Morals are relative, not absolute; that is to say, there is no fixed standard of right and wrong by which the actions of all men throughout all time are measured. The moral code advances with civilization; conscience is a growth. That which society in rude stages of culture approves, it condemns at later and more refined stages, although so great is the power of custom in investing what is old with sanctity, so persistent the claims of authority, and so deep its interest against changes which cannot fail to impair it, that moral qualities are grafted upon acts apart from any question of their bearing upon character. Such, for example, are the prohibitions against certain foods, and the commands to keep certain days sacred even to the extent, as not so very long ago, among the Puritans of England and America, and the Scotch people, of forbidding even the

doing of deeds of charity and mercy on Sundays, if these caused folk to work. Such too is the tyranny of caste, as among the Bhattias of India, who regard dining at an hotel as a greater sin than murder. Among the Mohammedan sect of the Wahabees murder and adultery are venial offences compared to the smoking of tobacco. Among many savage races it is worse to marry a girl within the tribe than to kill one of another tribe. And among ourselves, the rich and fashionable folk who are spoken of as 'society,' will less readily overlook a slip in his manners than the betrayal of a girl of humble station by a man of rank. Although there are signs of an unwise laxity towards offences for which death or life-imprisonment are the rightful penalties, the alterations in criminal codes in the present century witness to progress in morals and humaneness, and to the treatment of crime as more or less of the nature of disease.

At the beginning of this century there were above two hundred offences on the statute book for which death was the punishment, and, of these, one hundred and fifty had been added during the reign of the Georges. Men and women were hanged for sheep and horse stealing, for cutting down young trees, for shooting rabbits, for robbery of five shillings worth of goods from a shop; and, as late as 1827, a man found guilty of making spurious coins was drawn on a sledge to Newgate, and there hanged. These barbarous penalties, like those enacted against witchcraft down to the last century, were carried out

without protest from humane, educated, and religious men, and, therefore, from the great body of the people. The collective conscience of the nation never questioned the justice of what the law enacted, and, as with the abolition of slavery, the cruel code was modified and finally annulled, solely through the efforts of a few who had awakened to a higher sense of human rights and duties; men through whom the general moral tone was gradually advanced. That heightened tone, which is a yet stronger and still growing note of our time, is wholly due to the progress of science, using that term as including not merely knowledge of the operations of nature, but knowledge of human life brought about by freer intercourse among the classes that compose nations, and among nations themselves.

It is this best of all forms of education that has caused the growth of kindlier feelings, with the humaner treatment of criminals, paupers, and lunatics; and the enlargement of sympathy not only between man and man, whether white or black, but between man and the lower animals. Of course knowledge has been turned to base uses by the crafty, the selfish, and the cruel, but the ills caused thereby are as dust in the balance against the good which has been wrought. The conduct of a nation is no longer regulated solely by its own interests without regard to what is due to others, neither does it draw its sanction from the tribal legislation of a barbaric past, but from what, after ages of dearly bought experience, has proved itself to be best for man. In this, as in

aught else which endures, nothing is rigid or final. Man's capacity can never overtake the loftiest ideals after which the purest and noblest of his race have striven; in their conception is the spur to their pursuit. What dead weight of care do morals, thus regarded, lift from the heart of man! what new energy is given to his efforts! Thought becomes fixed on the evolution of goodness instead of on the origin of evil; time is set free from useless speculation for profitable action; evils once deemed inherent in the nature of things, and therefore irremovable, are accounted for and shown to be within our power to extirpate.

For in proving the unvarying relation between cause and effect in morals as in physics, science gives the clue to the remedy for moral ills. Moreover, that which man calls sin is shown to be more often due to his imperfect sense of the true proportion of things, and to his lack of imagination, than to his wilfulness; 'evil is wrought by want of thought as well as want of heart.' As Herbert Spencer says, 'the world is governed or overthrown by feelings to which ideas serve only as guides;' and the lack of imagination, which is itself largely due to defective training of the intellect, prevents a man from putting himself in the place of others, and deprives him of that sympathy which is essential to the unselfish life. Since morals are due to the social instinct, the highest morality is that wherein each one shares to the full the life of all. The terrible mass of wrong-doing can only be lessened and finally removed by suppression of the over-self; by the maintenance of the bal-

ance between such care of one's self as shall best fit us for the service of man, and such thought for others as shall inflict on them no suffering through our selfishness, nor loss through our gain. The crises of history are now rare when great principles or causes, demanding the sacrifice of the individual life, are at stake, but the world has never lacked a Curtius, and the spread of the scientific spirit has not proved fatal to the heroic.

Especially is science a preacher of righteousness in making clear the indissoluble unity between all life past, present, and to come. We are only on the threshold of knowledge as to the vast significance of the doctrine of heredity, but we know enough to deepen our sense of debt to the past and of duty to the future. We are what our forefathers made us, *plus* the action of circumstances on ourselves; and in like manner our children inherit the good and evil, both of body and mind, that is in us. Upon us, therefore, rests the duty of the cultivation of the best and of the suppression of the worst, so that the world be the better for our having lived in it. More imperious is that duty since nothing—not omnipotence itself—can step in between us and the consequences of our acts. The 'forgiveness' of which men talk shows the charity of the injured, and may win the wrong-doer to a better life; but the thing 'forgiven' —who can undo its effects? 'Our deeds,' says George Eliot, 'are like the children born to us—they live and act apart from our own will. Nay, children may be strangled, but deeds never.'

Self-conquest lies in obedience; obedience is attained through knowledge; and if to know that it rests with man to make or mar the lives of others be not sufficing stimulus to learning the true that we may do the right, no other motive can avail. Threats of punishment and promises of reward in an after life exercised no small influence on conduct in lawless and superstitious ages, and in some degree they influence the actions of the ignorant or timid, but their remoteness from daily life lessens their power; moreover, the world is outgrowing these and like beliefs the origins of which are made clear. And when all the detail with which word-spinners have overlaid them is swept away, we see what brief maxims suffice for the conduct of life. All the law and commandments are in the golden rule; all ethics in the teaching that if a man be true to himself he cannot be false to his fellows. As Emerson finely says, he will then be watchful not that his neighbour cheats not him, but that he cheats not his neighbour.

5. *Evolution of Theology.* Theology takes many forms, but it may be defined as dealing with man's relations to the god or gods in whom he believes; morals embracing his relations to his fellow-men. And we find the two thus roughly separated in all barbaric religions.

But they have become mixed in the degree that conduct has been made to rest upon supposed divine commands, given through sacred books and churches, as to what men shall and shall not do—an assumption which serves a useful purpose as a restraint upon the

passions of the brutal and ignorant, but which has been a powerful engine of terrorism in the hands of impostors and fanatics. Besides which, a moral code is weakened in the degree that it is bound up with dogmas the truth of which may be disproved.

No such danger exists when it is seen that the evolution of belief in spiritual beings is a thing entirely apart from the evolution of morals, which, as has been shown, are based on social instincts and sympathies guided by reason and strengthened by inheritance and practice. For primitive theology is primitive science; it is the outcome of man's first efforts to explain the nature of his surroundings, of the superhuman beings who appear to control him and them, and of the best way to approach those powerful beings. At this stage of his mental growth, the emotions have foremost play, because feeling precedes reason, and its exercise is more easy, its results more rapid, although, on that account, less trustworthy. Besides this, the phenomena on which experience, as the sole guide to true knowledge of things and of any order among them, is based, are too vast, often too slow in their changes, for a single life to compass, even were the reasoning faculties capable of dealing with them. It needed the lapse of time ere man found out that things were not what they often seemed to be, and therefore, that the first impressions of his senses had to be corrected ere he could reach the truth about his surroundings. So far as effort to supply the needs of his body sharpened his wits, he was not worsted; it was in his struggle against spiritual powers that his helplessness

was manifest. Ignorance, ever the mother of mystery, made him the slave of his fears. The vacuity of his mind gave entrance to all the demons of panic and terror. The universal instinct of the savage leads him to ascribe an indwelling life to everything that moves, from the sun in heaven and the drifting clouds to the rustling leaves, and the stones that roll from the hillside across his path. In this he acts as we see shying horses, timid pups, and young children act, until they learn from experience what things move of their own accord and what things do not. Shakespeare might have added Caliban to 'the lunatic, the lover, and the poet,' as of imagination all compact, and on whom it plays such tricks

> That if it would but apprehend some joy,
> It comprehends some bringer of that joy.

Ever on the alert against enemies, man's fancy multiplied them on all sides; and since he naturally attributed passions like his own to the unseen beings in whom he believed, he dreaded 'some bringer of that harm' from every quarter, especially from things near at hand whose dire effects touched him closely, as the whirlpool and the breaker, the falling tree, the devouring beast, or venomous reptile. Phenomena farther off and less fitful moved him less, but although day succeeded night, both sun and moon were in turn often swallowed and disgorged by the black cloud-monsters, and in the wake of the fire- and wind-dragons of the lightning and the storm there followed destruction and death.

What man fears, but is powerless to control, he seeks to appease. Hence the prominence of devil-worship, of belief in baleful spirits amongst lower races; hence, likewise, the persistence of kindred beliefs among the ignorant in civilised countries; hence the world-wide custom of averting the wrath of gods or of buying their favour by sacrifices, smearing their images with human blood, and wreathing them with human intestines. Hence also, the rise of a special class, 'medicine-men' and priests, into whose hands all ghastly and ghostly functions fall, and who secure dominance over their fellow-men by pretending to be the mouthpiece of the gods, to obtain acceptance of men's gifts by them, to forgive sins in their name and to make known their will.

This animism, or general doctrine of spiritual agents, was largely fostered by personal experience supplied by dreams about both the dead and living, hallucinations, swoons, and by the shadows or reflections which objects cast, all which seemed to witness to the existence of a second self or soul, that came and went at pleasure during life, and haunted its old home after death. The burial-place became the spot where the living brought their gifts to the dread spirits of the departed, whose worship is a leading feature of barbaric religions. The grave was the cradle of beliefs about the departed; the tomb became the temple. Combined with the belief in life wherever power or movement was manifest, these ideas have built up all theologies, from the polytheistic to the so-called monotheistic, the common element in each being the

ascription of personality to unseen powers. Given the intellectual stage which a people has reached, the character of their gods can be predicted, although the higher theologies will retain persistent traces of the barbaric conceptions of deity in which they arose. They are not, as shallow carpers have argued, the ingenious inventions of self-seeking men; they arise out of the necessity of human nature to frame an explanation of that which affects it deeply and constantly. Their roots draw nutriment from a common soil; the frenzy of the savage, the ecstasy of the saint, and the excitement of the revivalist, have a common base in undisciplined imagination.

Theology is purified from gross conceptions only in proportion as it is purged of the false science with which, to its own hurt, it identified itself in the past, and to the remnants of which it still clings. The function of science is to clarify the mind, and to show how the beliefs of the past are the myths of the present; the duty of theology is to readjust itself to what science proves to be true, otherwise it is doomed.

Creeds are born and die, remaining only curious relics of illusions over which men wrangled and fought. Rites and ceremonies, barbaric in origin, enter into the higher religions, serve a passing purpose, and, finally, become matters of merely antiquarian interest. But duty never lapses. While theology, assuming divine origin, concerns itself about the fate of the man who denies its assumptions and disbelieves its dogmas; morals are concerned only to warn him that what he sows he or his will reap in

the present life. In the end, when it is seen that theories about gods and all other spiritual beings have nothing whatever to do with man's duty to his fellows, he will occupy himself with that duty alone.

In the chapters now concluded a vast field, the limits of which shade into the unlimited on all sides, has been roughly surveyed. We began with the primitive nebula; we end with the highest forms of consciousness as presented in man. Let the final words be an epitome of what itself is only an epitome.

1. *Description.* The UNIVERSE is made up of MATTER and MOTION, *both of which are indestructible.*

MATTER consists of about seventy so-called elements, which exist in a free or combined state as solid, liquid, gaseous, and ethereal; between which states there is no break.

MOTION acts in a twofold and opposite way, viz., as a pulling or combining Force, and as a pushing or separating Energy. Force inheres in matter, and acts continuously whatever the distance; Energy is both passive or stored-up, and active or in a state of transfer from body to body, the sum-total being in gradual course of transfer to the ethereal medium, where its power to do work ends. Ponderable matter is distributed throughout space in bodies of various size and density, from molecules to sidereal or solar systems. Such a system is our central sun, with his company of planets and their moons, and of comets and other wandering gaseous bodies. The planet

on which we live is a nearly spherical body, seven-tenths of which is covered by water, and the whole surface enveloped by an atmosphere. So far as its rind or crust can be examined, it is found to consist of solid rocks, the lowest of which have been fused by fire, and the uppermost laid down by water. The water-laid rocks contain the remains of plants and animals which have escaped the general destruction of organisms in the wear and tear which the rocks undergo ceaselessly. The simplest fossils are found in the oldest deposits, the more advanced in the newer, and so on in ascending scale until we reach the newest deposits, which contain the highest forms. The existing species of plants and animals comprise the lowest and simplest, which have probably persisted throughout the entire life-period, as well as the highest and some others, the vast majority of intermediate species having died out. All plants and animals are made of the same materials, and have to do the same work. That work is three-fold: to feed, to multiply their kind, and to respond to the outer world. The cells of which every part of every plant and animal is built up are variously altered and arranged according to the way in which that work is more or less divided amongst the several parts. The main difference between plant and animal is in the mode of feeding; the plant is alone able, in virtue of its chlorophyll, to convert the inorganic into the organic, and the animal therefore depends on the plant for its food supply.

2. *Explanatory.* At the beginning of the present

universe Matter was a diffused vaporous mass, unequally distributed throughout space. Force, acting on the unstableness of that mass, drew its particles together, and the resulting collision set free the stored-up Energy, which became active in two forms: 1. the *molar*, causing the several masses into which the particles had gathered to spin round in an orbit; and 2. the *molecular*, causing a swing-like motion among the particles, which motion was diffused as light, heat, etc. The masses into which the primitive nebula was broken up became sidereal or solar systems, each of which, like the parent mass, threw off, as it was indrawn towards its common centre of gravity, masses which became the planets, and from these were detached, in like manner, masses which became moons. Both in its shape and general condition the earth gives proof of this passage from the gaseous to the solid state. As one of the smaller bodies, it long ago ceased to shine by its own light, but a vast period elapsed before it became cool enough to form a crust and to condense the vapours that swathed it into primeval oceans. The simplest compounds of its elements were formed first, the combinations becoming more and more complex, until they reached that subtle form called 'protoplasm' which is the 'physical basis of life,' and which, starting in water as a structureless jelly, has reached its fullest development in man. The organic is dependent upon the inorganic, and mind is the highest product of the action of Motion upon Matter. From the action of mind on mind has arisen that social evolution to

which, in a supreme degree, is owing the progress of man in knowledge, whereby he has subdued the earth.

The ultimate transference of all energy to the ethereal medium involves the end of the existing state of things. But the ceaseless redistribution of matter, force-clasped and energy-riven, involves the beginning of another state of things. So the changes are rung on evolution and dissolution, on the birth and death of stellar systems—gas to solid, solid to gas, yet never quite the same. Thus the key-notes of Evolution are Unity and Continuity. All things are made of the same stuff differently mixed, bound by one force, stirred by one energy in divers forms. Force inheres in matter; Energy acts through it; therefore both have neither more nor less claim to objective reality than matter. And as science tends to the conclusion that all kinds of matter are modifications of one primal element, and that all modes of motion are varied operations of one unknown power, perchance these three—Matter, Force, and Energy—are one.

But into these and like speculative topics Evolution does not intrude. Dealing with processes, and not with the nature of things in themselves, it is silent concerning any theories that may be formulated to gratify man's insatiate curiosity about the whence and whither. Since it can throw no light on the origin of Matter or Motion, if origin they had; or on the beginnings of life or of mind, it leaves great and small alike a centre of impenetrable mystery.

To know the limits of our knowledge is no small gain, since the time that we might otherwise waste in

unavailing enquiries is turned to profitable use in that study of the works and ways of nature which we can pursue to the end of life without satiety, and in the recognition of the demands of others upon us which will always exceed our powers of satisfaction.

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